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PRELIMINARY REPORT ON OBSERVATIONS OF MARS MADE AT MOUNT WILSON IN 1956*

By Robert S. Richardson, Ph.D.†

The 60-in. and 100-in. telescopes on Mount Wilson were made available for our programme on Mars in 1956 for 36 nights from May 5 to December 16, inclusive. Of these 21 nights were from August 10 to September 13. Only two nights were lost through clouds. During 110 hours of actual observation there were 7 nights when the seeing was poor, 13 when it was fair, and 14 when it was good or very good. About twice as much time was spent on Mars in 1956 as in 1954,[1] under generally superior observing conditions.

The Programme for 1956

The programme adopted for 1956 consisted of three distinct types of observations: (1) direct photographs at the Cassegrain focus of the 60-in; (2) high dispersion spectra at the coudé focus of the 100-in.; and (3) photographs of the satellites at the Newtonian focus of the 60-in. and 100-in. telescopes. The danger in such diversity is that if only a few observations are obtained owing to adverse conditions the whole programme may fail. Fortunately good weather enabled all three to be carried out practically as planned.

Visual and Photographic Observations of the Disc

In 1953 Pettit[2] called attention to the fact that the visibility of the canals depends rather critically upon the season in the southern hemisphere of Mars. The canals first appear most satisfactorily when the date in the Martian southern hemisphere corresponds to about April 1 in the United States, and by the middle of June little is left of them. Very few canals are visible during the south Martian late summer, autumn, and winter. In 1956 south Martian April 1 came on May 23, when the planet was 82,000,000 miles away. When Mars was closest in September, 1956, the Martian date corresponded to about June 10. Hence the opposition of 1956 did not appear to be particularly favourable for studying the canals.

* Read as a part of the Symposium on Mars at the meeting of the American Astronomical Society in New York, December 26–29, 1956.

† Mount Wilson and Palomar Observatories, Carnegie Institution of Washington, California Institute of Technology.

Direct photographs of Mars were taken at the Cassegrain focus of the 60-in. with a camera and enlarging lens that at opposition during good seeing could be used to give an image of Mars 10 mm. in diameter.* The exposures through different filters were made on Eastman IV-F plates, a high contrast fine-grained emulsion nearly uniform in sensitivity throughout the visible spectrum. A few exposures in the infra-red were taken on IV-N plates. The plates were calibrated with a tube photometer using the same filters as those on the camera. Details concerning the exposures are given in Table I.

TABLE I

PHOTOGRAPHS OF MARS TAKEN AT THE 60-IN. CASSEGRAIN

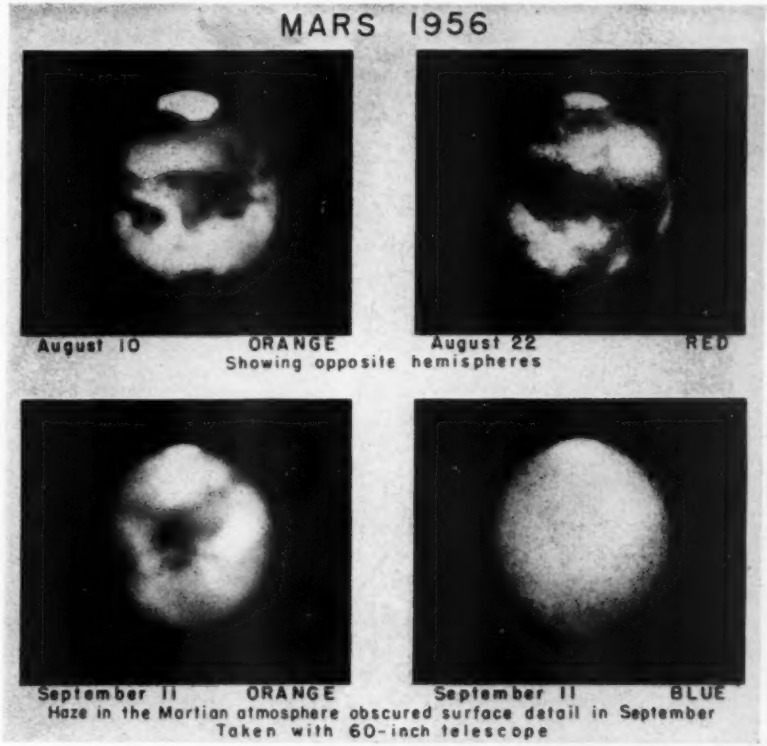
	Number of Exposures	Emulsion	Filter	Exposure Time
Orange ..	225	IV-F	3486 (Wratten)	0·3 to 1·3 sec.
Infra-red ..	24	IV-N	—	6 ,, 20 ,,
Blue.. ..	158	IV-F	BG4 (Schott)	10 ,, 20 ,,
Green ..	15	IV-F	2014 (Corning)	0·3 ,, 1·3 ,,
Red	15	IV-F	2418 (Wratten)	0·6 ,, 1·3 ,,

Although some test exposures were taken on Mars in May they were unsatisfactory owing to thin clouds. The next opportunity occurred on the morning of June 3 under very favourable conditions. The sky was clear and the seeing estimated as 6 on a scale that is probably about 8. The altitude of Mars was 28°. The season in the southern hemisphere corresponded to our April 8. I was familiar with the appearance of Mars at the 60-in. under high magnification from my work there in 1954, but this morning the disc had a peculiar aspect which I had never noticed before. There were innumerable irregular blue lines extending across the bright red regions like veins through some mineral. Several minutes passed before it occurred to me that these markings must be canals. I was taken completely by surprise as I had no thought of seeing canals at a distance of 75 million miles. Their colour also was disconcerting. Experienced observers such as Schiaparelli, Lowell, and W. H. Pickering, apparently never saw colour in the canals, but described them as dark or grey. These lines appeared distinctly light blue, the same colour as the maria. In fact, they appeared to be narrow extensions of the maria into the deserts. Pettit has recorded the colour of the canals as olive-green and very evident in the summer of 1939.[3]

Although several good photographs of Mars were obtained that morning, the images 3 mm. in diameter failed to show the irregular lines that were easily apparent to the eye under high magnification. The only other time I saw canals was on October 10 at the coudé focus of the 100-in., when the far southern canals *Simois* and *Thermadon* were visible in only fair seeing. I suspected others, but I was able to hold these for a second or two. They appeared as dark straggly streaks, extending between the south polar region and the *Mare Sirenum*.

Our most interesting photographs are probably those taken in orange light

* The camera was made under the supervision of Dr. Dinsmore Alter from funds supplied by the L.A. County Park Board.



on August 10, when Mars was 39,800,000 miles away. Images of equal quality were secured earlier, but they are too small to show much detail. At opposition the surface features were rendered hazy by a dust storm on Mars which apparently began about August 30.[4] The best images of Mars 6 and 8 mm. in diameter taken in orange light on August 10, show the canals *Gehon*, *Hiddekel*, *Cantabras*, *Agathadaemon*, *Ganges*, *Nectar*, *Nilokeras*, *Draco*, and *Jamuna*. They show on the negatives as light wispy streaks. From a study of these photographs and my admittedly casual visual observations made hurriedly between exposures, I am convinced of the existence of streaks on Mars at approximately the position of well-known canals. They convey to me the impression of being some natural surface feature.

In 1954 our blue images showed several conspicuous bright clouds as well as a general clearing of the atmosphere for a few days near opposition. At the opposition of 1956 our blue photographs showed only a uniformly blank disc except for the polar cap. Since our observations are scattered we could easily have missed a few days of blue clearing.

The new dark area centred at 255° + 30°, which attracted so much attention in 1954, was still present with about the same shape and size as before.

The maria were carefully examined for colour whenever observations were made from June 3 to September 13. The colour appeared as slate-blue regardless of the telescope, the focus used, and the seeing. This colour of the maria was confirmed by other observers who happened to be nearby. But when I observed Mars on October 10 at the coudé focus of the 100-in. the maria appeared to me as light green or grey-green. No blue tint was evident. The last time I observed Mars was also at the coudé focus of the 100-in. on December 15, 1956, at about 4^h UT, in fairly good seeing. The maria appeared as a well-marked dark greyish-green band, with again no trace of blue.

Plate I, a, shows Mars photographed in orange light on August 10, when the longitude of the central (LCM) was 13°. Plate I, b, is a photograph of Mars at the 60-in. in red light on colour film by Robert Leighton of the California Institute of Technology. Plate I, c, shows Mars in orange light on September 11, LCM = 55°, after the dust storm had developed. Notice on September 11 that the whole disc has a hazy appearance and certain features are blotted out altogether, such as the *Solis Lacus* and the *Margaritifer Sinus*. Plate I, d, shows Mars photographed in blue light on September 11 (LCM = 58°).

A great rift in the south polar cap was a conspicuous sight about the middle of July. This rift shows on our exposures in orange light taken on July 20 at $7^h.7$ UT. It cannot be seen on blue images of equal quality taken 10 minutes earlier.

High Dispersion Spectra of Mars

Kuiper[5] has identified two bands of carbon dioxide in the spectrum of Mars at 1·6μ. From an analysis of Kuiper's data, Grandjean and Goody[6] have found the Martian concentration of carbon dioxide to be 50 times the terrestrial concentration, and the total amount in gm./cm.^{2} to be 13 times greater. The amount of carbon dioxide appeared so high that Pettit suggested I make a search for the λ7820 band of CO_2 in the spectrum of Mars. It was the discovery of the λ7820 band in the spectrum of Venus that established the presence of carbon dioxide in that planet's atmosphere.[7] This band does not appear in the solar spectrum even with a very low Sun.

The first spectra of Mars were taken July 18, 19, 20 at the coudé focus of the 100-in. with the 114-in. camera. The region λ7600–λ8400 was photographed on I-N plates ammoniated in the first order of the 46B grating with a dispersion of 5·6 A/mm. With the image rotator the disc of Mars could be orientated to any desired position relative to the slit and held fixed during the exposure. With this device spectra of particular regions of the disc could be obtained, such as the Syrtis Major, the new region at 255 + 30°, the south polar cap, etc. Four spectra of the λ7800 region were examined on the comparator beside a spectrum of Venus of the same dispersion which showed the λ7820 band of CO_2. The head of this band falls in a region singularly free from absorption lines. No trace of the band could be found on any of our spectra of Mars.

The next spectra of Mars taken in August were photographed on higher contrast IV-N plates. To secure a long path in the planet's atmosphere the slit

was set on the limb, the particular point selected being the south polar cap. Other spectra were taken with the slit across the central meridian of the disc. These plates also failed to show the band. Some plates taken in October, and several taken in December near quadrature, gave negative results as before.

The Search for Evidence of Oxygen

Our infra-red spectra of Mars also show the A band of O_2 at λ7600, as well as a host of water vapour lines from about λ7900 to λ8400. In 1933 Adams and Dunham[8] searched for displacements in lines of the B band of O_2 at 6900 in the spectra of Mars without result. During these observations the radial velocity of Mars relative to the Earth ranged from $-$ 13·8 km./sec. to $+$ 12·6 km./sec. During our observations the radial velocity of Mars ranged from $-$ 8·9 km./sec. on July 18, to $+$ 14·9 km./sec. on December 16, corresponding to a displacement at λ7800 of 0·22A or 0·03 mm. on the plates, to 0·38A or 0·07 mm., respectively.

The (0, 0) A band of O_2 would seem to be much better suited for the investigation of oxygen in Mars than the (1, 0) B band, owing to the greater intensity of possible Martian components. King[9] found that the A band could be detected through 7 m. of air at normal pressure, while a path of 40 m. was needed to show the B band faintly.

From their work on the B band Adams and Dunham estimated the ratio Martian O_2/terrestrial O_2 as 1·5/1000. It would be very helpful if we could compare lines in the A band with lines of O_2 of about this relative degree of abundance. Now it happens that we can actually do this, owing to the presence of isotope lines in the A band due to the molecule $O^{16}O^{18}$, which have an abundance of 1/1250 relative to $O^{16}{}_2$. A detailed study has been made of the lines in the A band from solar spectra taken at the 150-ft. tower with a dispersion of 0·44A/mm. The lines most suitable for measurement are those in the R branch, the strongest of which have an intensity on the Rowland scale of about 30. The corresponding isotope lines have an intensity of 2 or 3. But the strongest lines in the A band are so wide that in the spectrum of Mars the isotope lines can only be detected with difficulty even when they occur entirely in the clear. It might seem that lines in the A band of about intensity 12 which are much narrower would be more favourable for detecting possible Martian components. On the plates of December 16 the velocity is high enough so that any Martian lines should be just separated from the weaker telluric lines of the band. No evidence for such Martian components can be found from inspection of the plates. Microphotometer tracings will be needed to settle the matter.

It is my personal opinion that the method of velocity shifts is not sufficiently sensitive to give us definite information about the quantity of oxygen in the Martian atmosphere. Some entirely new technique should be tried, such as rocket spectra of the Moon and Mars taken above 100 km. where O_2 is supposedly all dissociated.

The Search for Water Vapour

The foregoing remarks are also generally applicable to the search for displacements in the telluric lines of water vapour due to possible weak Martian

components. In the case of water vapour, however, there is another test that seems worth trying. The polar caps indicate there must be *some* water on Mars. It is unlikely that this moisture is distributed uniformly throughout the planet's atmosphere. Thus the presence of water vapour in the Martian atmosphere might conceivably be detected from slight *variations* in the intensity of the lines of H_2O over the disc. That is, the lines might appear stronger where the slit fell across the maria and polar regions than the surrounding deserts. From spectra of the Sun taken at different altitudes water vapour lines were selected that seemed especially sensitive to differences in air path. These lines and others were examined in spectra of Mars on which the maria and south polar cap were particularly well defined. No significant variations could be discerned in the intensities of the water vapour lines over the disc.

The Opacity of the Martian Atmosphere

Photographs of Mars in yellow and red light penetrate the atmosphere and show the surface features. Photographs of Mars in blue and violet light usually show only a blank disc except for the greatly enlarged polar cap. The atmosphere must become opaque at some wave-length between the yellow and blue. Spectra of Mars from λ3600–λ5800 were taken with the 114-in. camera in the second order to determine where the maria became indistinguishable from the surrounding disc. The polar cap appears like a bright border on many of these spectra. On spectrograms taken August 25 from λ4000–λ5000, the light streak due to the maria can be followed with certainty to λ4600. Six independent eye estimates of where the maria became indistinguishable from the disc ranged from λ4260 to λ4580, with the mean at λ4420. The south polar cap, on the other hand, appears with increasing intensity relative to the disc from λ5830 to the limit of our spectra at λ3525. It is hard to resist the conclusion that there must be two polar caps, as suggested by W. H. Wright[10] in 1924; the small surface cap that we can see and photograph in visual light, and a much more extensive over-lying atmospheric cap that registers so strongly in the photographic region.

Photographs of the Satellites

Information on the internal constitution of Mars is greatly desired in the study of the evolution of the solar system. For example, does Mars have a dense central core like the Earth? Or is it nearly uniform in composition like the Moon? Information on the internal constitution of a planet can be obtained from its oblateness. Measures of the form of Mars either by photography or the micrometer are particularly difficult, however, owing to errors arising from the varied colour of the surface, residual phase, and atmospheric effects. But the oblateness may also be determined independent of such errors from perturbations in the motions of the satellites. For this purpose positions of the satellites are needed over a period of many years. It is hoped that positions of the satellites determined from our photographs at this opposition will have some small share in contributing to the solution of this problem.

I wish to thank Thomas Cragg of the Mount Wilson Observatory for help in identifying the canals on our photographs.

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PSYCHOLOGICAL CONSEQUENCES OF SPACE TRAVEL

By E. Jack Wilcox, Ph.D.

Introduction

Some of the physical conditions which the crew of a spaceship must accept will have definite psychological consequences upon the emotional condition.

There is first the need to conserve space inside the ship, which, together with the lack of gravitational pull, makes it desirable to adopt a design with floor space around the entire circumference of the cabin. Another point is that our spaceship must be something of a flimsy structure in order to save weight; as little stress as possible must be put on the superstructure of the cabin through internal air pressure. The spaceship occupants who have become accustomed to these conditions could operate adequately under a pressurized cabin atmosphere of about 3 lb. per sq. in.* which roughly corresponds to the pressure at 35,000 ft. above sea level and is sufficient for bodily needs. A complete or nearly complete oxygen atmosphere with purifying mechanisms would eliminate the need for oxygen masks, and if it was thought that greater pressure could be tolerated, the oxygen content could be adjusted accordingly. Under these rarefied air surroundings, the ability to transmit sound verbally is somewhat reduced, some 15 or 20 per cent. more effort being necessary on the part of the speaker to project his voice to the equivalent of at sea-level pressure.

We can see from these few brief comments that the crew member is going to experience many physical differences in such an environment. His visual perceptions will include other individuals standing upside down; he will hear them speak less clearly and will have to exert an effort greater than normal to bridge vocally the gap between himself and them. He will feel no weight, having to force his hands down as well as up. Unless some suction cups are attached to the feet, he may propel himself more with his hands and arms than with his legs. No feeling of being in or off balance will come to him, and if he starts to

* Although the article is constructed around the figure of 3 lb. per sq. in. pressure, this is a controversial point. The desirability of normal atmospheric pressure is obvious, and the adverse psychological influences described would be relieved as pressures approach the sea-level figures.

sit down—though he cannot be tired of standing—he will lift his legs rather than lower his body.

In short, our crew member will be feeling quite strange. Many of the habit patterns established over the years from birth which have become quite unconscious in their execution will suddenly be brought to awareness by virtue of their different results. Conscious mental effort will have to be employed to do what formerly was automatic and unconscious and it is in these conditions that our crew member must perform intricate technical operations and undertake a journey with immense risk and personal danger to himself.

Onset of Psychosis

We know that emotions are disturbed when urgent needs are not satisfied. The emotional response is to assist survival by "getting excited" about something that is necessary but not forthcoming. This increases the chances that we will get it. However, with certain conditions in childhood, survival depends upon remaining partially "excited" all the time if certain vital essentials are to be obtained.

Frustration of the needs of the individual from without brings an aggressive urge from within, though this may have to be curbed because of external punishment. It is obvious that some emotional controls can be much better than others. Since all of us need such controls, we look upon certain ones of them as normal and these we call "sublimations." Less efficient controls which have to be employed only when emotional stress becomes very great are called "psychotic."

Among psychologists, "psychotic break" refers to the breaking loose of feeling from its previously adequate controls. It is at this point that the psychotic controls must be called into service and these are chiefly of a "reality distorting" nature. For example, the shock of the death of a loved one may be too great to bear and the idea that the death did not occur takes on a reality of its own and is called a "delusion." This is a psychotic control. Much perceptual reorganizing may occur to support delusional ideas with things heard or seen or felt, taking on the character of confirmation of the validity of the delusional idea. This inner environment overrides the outer and more realistic environment for reasons of emotional equilibrium. Inner feelings tamper with the data obtained from sensory organs and change hard facts into more desirable fictions. With this freedom in distorting surroundings, the need to express hostility can quickly find a reason for doing so in the environment. It becomes justifiable to pour anger on to a best friend because this friend is being seen as an intentional persecutor. Free expression can be given to great fear because of the seemingly clear intention of neighbours to do harm. Excessive guilt can be felt because of the overwhelming evidence of one's wrongdoings. In all these instances, emotion is controlling the understanding rather than the reverse.

The Emotional Pressure of Outer Space

We can take as an example at this point a crew member who is emotionally disturbed underneath, but whose defences against the inner turmoil are good and do not permit it to show on the surface. After a time boredom or frustration

with the living conditions in the spaceship add to his anxiety and his hostility, which already existed but were under control. He may then find it necessary to withdraw a little from his external contacts to reinforce his controls; however, in doing so, he does not quite have the rapport with his fellow crewmen that he did before. His calculations may suffer a little from his preoccupation with inner thoughts, and when another crew member shows some irritation towards him, he feels angry, hurt and guilty. More emotional pressure is put on his already weakened control, and further withdrawal is necessary for reinforcement. We now have a vicious circle under way and trouble is bound to occur.

Conditions within the spaceship can contribute to the onset of reality distorting or psychotic perceptions. The surroundings are such that our individual cannot possibly perceive in the ordinary sense and many of his automatic habits necessarily have to be changed. His lack of feeling "solid" on strictly a physical basis, does not help his emotional "solidity." He does not have to imagine for emotional reasons that he can float in mid-air—he really can! His environment can lend impetus to his emotional tension, not to his habits of control as is usually the case.

Prevention and Treatment of Emotional Problems in Space

The most obvious prevention of emotional disturbance is by the careful and skilful selection in the first place. There are many diagnostic procedures in use to evaluate the emotional state, with especial regard to the amount of tension existing in a given individual. The very frequent concern of many of these examinations is whether or not the patient is psychotic or potentially so. If we select the most stable individual in the first place, we are on better ground.

However, there is quite a passage of time before the spaceship reaches its destination, and therapeutic technique used in clinical settings might easily be adapted to this need. It is the group therapy approach to emotional disturbance. The group in the ship could have their therapist present by loud-speaker and he could help to elicit feelings and encourage communication between crew members in such a way as to keep at a minimum inter-personal misconceptions, jealousies, and antagonisms.

Aside from regular group therapy sessions, contact with personally important matters of home and family could be supplied by radio or television. In addition to this, plenty of work should be assigned to keep the crew busy and free from boredom. Much of this could be in the form of making and reporting various observations.

A simulated run should be worked out experimentally before the actual trip occurs, with especial attention to types of personalities which operate together successfully on such ventures, as well as for the purpose of selecting a crew on the basis of persisting freedom from psychopathology. We might, for example, find that a rather "meticulous" second officer-in-command led by a more "expansive" commander make for less tension than the reverse. There are many personality variables which have nothing to do with pathology that might serve to keep emotional peace on such a long and confining journey. The research that is going on at present in the aircraft industry may be of great

help along these lines. However, we will be on safer ground if we carry out specific research on these problems previous to the actual venture of space-flight.

We cannot expect to anticipate all of the conditions which might be of psychological significance during a flight to outer space. However, we can emphasize that these are matters of real and practical importance, and hope through doing it, and we will encourage a greater study on the subject.

SKIN HEATING DURING RE-ENTRY OF SATELLITE VEHICLES TO THE ATMOSPHERE*

By T. R. F. Nonweiler, B.Sc.

SUMMARY

By paying special attention to the wing design and altitude of flight, it is possible to ensure that the highest temperature reached at the leading edge of the wing of an aircraft, in level flight at speeds of the order of the circling velocity need be no more than 1,000° C. Formulæ and charts are presented to enable the actual skin temperature close to the nose to be predicted, for a wedge-shaped wing, in terms of skin thickness and conductivity.

NOTATION USED IN MAIN TEXT

L	wing loading.
L_m	measure of L in kg./sq. m. (1 kg./sq. m. = 0·205 lb./sq. ft.).
Q	constant chosen so that $Q/\sqrt{x}$ approximates to rate of heat transfer per unit surface area from boundary layer close to leading edge.
Q_{max}	maximum of Q with respect to flight speed (achieved for $q_1^2 = \frac{3}{2} gR$).
$Q(\delta)$	value of Q relative to that for flat plate moving parallel to itself, at same speed, and having same surface pressure.
R	Earth's radius.
T	surface temperature.
T_{LE}	value of T at wing leading-edge.
T_{max}	maximum of T_{LE} with respect to flight speed (achieved for $q_1^2 = \frac{3}{2} g\ R$).
d	skin thickness.
d_m	measure of d in cms.
f	non-dimensional temperature defined by equation (1), and evaluated in Fig. 2.
g	gravitational acceleration.
k	thermal conductivity of skin.
k_m	measure of k in cals./cm. sec. ° C. (1 cal./cm. sec. ° C. = 242 B.Th.U/ft. hr. ° F.).
l	characteristic length of surface affected by conductivity, and defined by equation (2).
p_δ	surface pressure on underside of wedge aerofoil, taken as constant (measured in atmospheres).
q_1	speed of flight (measured in km./sec.).
x	distance from leading edge.
x_m	measure of x in metres.
δ	inclination of under-surface of wedge to direction of flight (positive if forward-facing).
ϵ_e	emissivity of external surface of underside of wing.
ϵ_i	rate of nett heat loss by radiation per unit area of interior surface of underside of of wing $\div \sigma T^4$.
σ	Stefan's Constant ($= 5{\cdot}7 \times 10^{-8}$ watts/sq. m. ° C.^{4}), ($= 1{\cdot}73 \times 10^{-9}$ B.Th.U/sq. ft. hr ° F.^{4}).

1. Introduction

At speeds of flight usual for present-day aircraft it is well-known that due to aerodynamic heating, the wing surface of an aircraft—at least near its nose—reaches the "thermometer" temperature whose value depends only on the speed of flight. If the same were true at such speeds as would, for example, be involved in flight of satellite vehicles, the consequences would be profound, because the corresponding thermometer temperatures are of the order of 10,000° C. and more. Fortunately, it is not true, and the present report discusses one limit to the maximum temperature reached close to the wing leading-edge, in sustained level flight at such speeds, as imposed by the action of conduction of heat within and along the skin. There may well be other and indeed lower limits, but the one considered can be established with a fair amount of certainty, even if it represents an unnecessarily pessimistic view of the intensity of kinetic heating.

The results we deduce are relevant only to a wing of wedge section (constructed as a hollow shell with a thin skin), not because of any particular merit that this section may have, but because the boundary layer flow about it may be most easily deduced for flight at such extreme speeds as those we have in mind. In the same way, the aircraft might well not be designed as a "flying-wing" so that the temperature reached by the fuselage would also present a problem of some importance. However, as we shall show that the wing loading must be low, and the wing thickness (or wedge angle) can be without penalty very large, it is likely that an all-wing design might after all be involved.

We first of all establish (in section 2) how we may determine the limit to the skin temperature, and also the rate of heat transfer at extreme speeds. Details of this latter determination are given in reference 2, and as the flow in the boundary layer is affected by the intense shock wave developed by a wedge at incidence, it is necessary also to discuss the relevant shock-wave conditions: this is done in reference 6. We next suggest (in section 3) measures which may be adopted to reduce the maximum skin temperature found by these means; and finally, by way of illustration, we calculate numerical values of the temperature reached by an aircraft, designed to include these measures, and flying at the particular speed at which kinetic heating effects are most severe. This speed is incidentally shown to be equal to just over 80 per cent. of the circling velocity (namely, 6·5 km./sec.). It is the intention to show that particular attention to the flight plan and overall design can greatly simplify the problems of kinetic heating. Nose temperatures of no more than around 1,000° C. are all that need be involved. Downstream of the nose the temperature will, of course, become progressively smaller still, but it is not our object to determine anything other than a limit to the maximum values.

2. The Deduction of a Limit to Skin Temperature

Supposing that there are no regions of turbulent flow, and that steady conditions prevail, the highest temperature will be reached at the nose of the body or wing surface, where the heat transfer is greatest. As mentioned in the introduction, in what follows we shall be dealing expressly with a wedge-shaped wing

* *A paper presented at the International Astronautical Congress in Rome*, 1956.

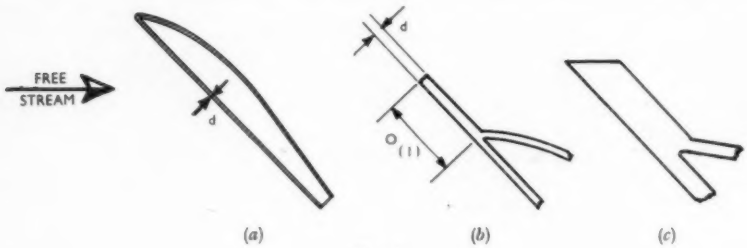

FIG. 1

(Fig. 1*a*) constructed as a hollow shell. The surface pressures in inviscid flow over such a wing are constant on the upper, lower and base surfaces, and the usual approach of boundary layer theory shows that at the nose, the rate of heat transfer due to kinetic heating is infinite, unless the local surface temperature has the particular "thermometer" value. If this approach were indeed valid, then it would follow that a non-conducting skin would instantaneously heat up to the thermometer temperature characteristic of the flight condition.

However, the argument which leads to this deduction can be faulted on two counts. In the first place, the rate of heat transfer is *not* likely to be infinite at the nose, and the theory which predicts such a singularity breaks down in this vicinity. For a start it is well-known that the simplified form of the Prandtl equations of motion and of energy, usually invoked in boundary layer analysis, are inapplicable in this region, and the full Navier Stokes equations are to be preferred, though they have proved intractable. Quite apart from this, there are modifications to the usual solutions to account for the self-induced pressure field of the boundary layer, and the proximity of the leading-edge shock wave, and also to account for the existence of a velocity of slip and a temperature jump at the surface. All of these factors are known to produce effects of increasing importance towards the leading-edge, which might well determine a maximum rate of heat transfer. Whilst orders of magnitude of this maximum rate can be estimated by existing analyses, it is not considered that sufficient is known as yet to predict the value with any certainty.

In what follows we shall treat the usual approximations to the rate of kinetic heating as valid right up to the leading-edge, and although this is plainly wrong, it does err on the pessimistic side in providing a local over-estimate of heat flux. But even then it does not follow that the nose will heat up to the "thermometer temperature," because the second assumption we mentioned in connection with this deduction can also be faulted. This is that the skin is a non-conductor of heat. Whilst this may be an adequate assumption in dealing with the surface temperature distribution downstream, it can certainly lead to important errors in the vicinity of the nose, where—if the skin were really non-conducting, there would exist severe longitudinal temperature gradients; even in a medium of small conductivity these gradients would imply an appreciable longitudinal rate of heat flux along the skin, which would tend to "cool" the nose at the expense of the structure downstream.

The problem of the action of conductivity in limiting the nose temperature has been discussed elsewhere.[1] The assumptions of this analysis are that:

(i) The skin is of uniform thickness d, which is small compared with the characteristic length l of the region affected by conductivity (to be defined later).

(ii) The rate of kinetic heating per unit area to the external surface is $Q/x^{1/2}$, where x is the distance from the nose, and Q may be taken as a constant over the length l. (The value of Q may be different on upper and lower wing surfaces.)

(iii) The exterior surface loses by radiation a nett heat flux equal to $\epsilon_0\sigma T^4$ where σ is Stefan's constant, and T the surface temperature; and the interior surface suffers a nett loss of heat by radiation equal to $\epsilon_i\sigma T^4$.

(iv) The interior of the shell formed by the wing skin is non-conducting.

Then it follows that

$$T = \left[\frac{Q^4}{(\epsilon_0 + \epsilon_i)^3\sigma^3 kd}\right]^{1/13} f\left(\frac{x}{l}\right) \quad .. \quad .. \quad .. \quad (1)$$

where l is the characteristic length and

$$l = \left[\frac{k^4 d^4}{(\epsilon_0 + \epsilon_i)\sigma Q^3}\right]^{2/13} \quad .. \quad .. \quad .. \quad .. \quad (2)$$

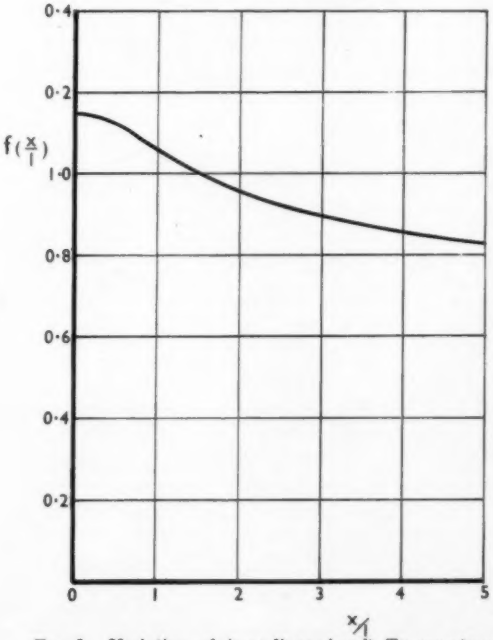

FIG. 2. Variation of (non-dimensional) Temperature with distance along surface.

These relations can be deduced on the basis of dimensional homogeneity, and the function f satisfies a non-linear second-order differential equation. The function f is shown in Fig. 2, which represents the result of a more refined method of solution of the differential equation involved than that given in the reference work. The evaluation of the maximum temperature which—as will be seen from Fig. 2—is attained at the nose ($x = 0$), is possible once we have allotted a suitable value to the constant, Q. As the heat transfer at, or close to, the nose depends only on the local value of the surface temperature, and not on its downstream variation, it is

possible to evaluate Q by reference to calculations of the heat transfer to surfaces with constant surface temperature, which fortunately is the condition most usually studied. This temperature is placed equal to T_{LE} and then the relation

$$T_{LE} = 1{\cdot}15 \left[\frac{Q^4}{(\epsilon_0 + \epsilon_i)^3 \sigma^3 k d} \right]^{1/13} \quad .. \quad .. \quad .. \quad (3)$$

obtained by noting that $f(0) = 1{\cdot}15$, is an implicit equation for T_{LE}.

At extreme flight Mach numbers it was shown in ref. 2 that Q is nearly independent of the surface temperature—unless it has improbably high values. It is only flight at extreme speeds which interests us in the present discussion, so that the results of this reference work will be invoked. They are relevant to the laminar boundary layer on a surface at uniform pressure p_δ moving at velocity q_1, and inclined at only a small angle of incidence to the flow, and they show that

$$\frac{Q}{x^{1/2}} = 44 q_1^2 \left(\frac{p_\delta}{x_m} \right)^{1/2} \text{kW/sq. m.}$$

where q_1 is in km./sec., p_δ is atmospheres and x_m in metres. This dimensional form of the result demands no assumption about the atmospheric conditions prevailing at high altitudes, which is to its advantage. However, we require a knowledge of the value of Q for forward-facing surfaces inclined not at a small, but rather at a large angle δ to the direction of motion. We find in fact from reference 6 that if dissociation effects are ignored

$$Q = 44 Q(\delta) q_1^2 p_\delta^{1/2} \text{ kW/(m.)}^{3/2} \quad .. \quad .. \quad .. \quad (4)$$

where the function $Q(\delta)$ is shown in Fig. 3 for all angles δ below that for shock-wave detachment at high speeds. This is taken to be about 50°, which is higher than the figure usually quoted: however, the figure used is based on an allowance for the change in the specific heats of air at the elevated temperatures existing behind an intense shock wave. The precise form of these allowances is detailed in reference 6, and a comparison of the variation of $Q(\delta)$ obtained by assuming the specific heats constant is proved in Fig. 3. In this matter it may also be pointed out that some investigators have suggested that radiation from the gas downstream of an intense shock-wave itself are such that it can be treated as virtually an isothermal process, in which event the corresponding form of the function $Q(\delta)$ approximates simply to $Q(\delta) = \cos^2\delta$, also shown in Fig. 3.

It will be noticed that all these assumptions lead to the deduction that the heat transfer reduces with increasing surface deflection, δ. The adopted assumptions of the present work suggest in fact a reduction intermediate between the others. This reduction over a forward-facing surface may appear unreasonable unless it is recalled that the comparison is based on surfaces subjected to equal pressure (p_δ). An inclined surface will only preserve this same pressure if the altitude of flight is higher, and the speed of flow outside the boundary layer is lower. If the altitude were kept the same, then, of course, the inclined surface would be subjected to a much higher rate of heat transfer. For all rearward facing surfaces, the results of reference 2 remain unaffected and the value of $Q(\delta)$ can be consequently taken as unity for $\delta \leqslant 0$.

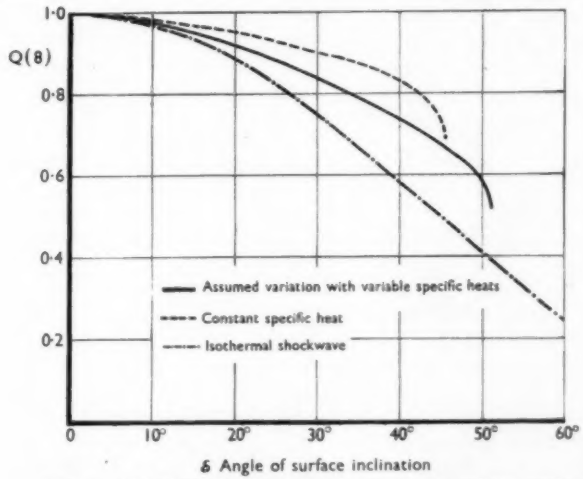

FIG. 3. Relative reduction in heat transfer on inclined surface as effected by assumed state of air properties.

The above discussion was prefixed by the statements that there were to be no regions of turbulent flow, and that steady conditions prevail. Whether or not steady conditions prevail, will largely depend on the flight plan: in all consequent assessments we shall take the wing to be on an aircraft in steady level flight. But it must be pointed out that in most other conditions of interest the rate of heat transfer at the nose is so large that steady conditions would at least be quickly reached in the region affected by conductivity.

Again, in regard to the implied possibility that higher rates of kinetic heating—and with them, higher surface temperatures, might be reached in regions of turbulent flow, if present, it should be noted that over a forward-facing inclined surface the flow outside the boundary layer has a relatively small Mach number (of order unity) and a very high temperature (of order M_1^2 times that of the ambient air, if M_1 is the flight Mach number). Thus, the ratio of surface to local static temperature is in all cases of interest small (and much less than unity). Almost certainly this would suggest that the rate of heat transfer is sufficiently large to stabilize the boundary layer in all disturbances; research in this field[3] has already deduced this to be true at least for two-dimensional wave-type disturbances in such conditions, whatever the Reynold's number of the flow.

3. Measures for the Reduction of the Maximum Skin Temperature

Equations (3) and (4) above provide a basis for the calculation of the maximum skin temperature. Without introducing any numerical values, they permit us to deduce qualitatively those measures which will reduce its value.

For instance, increase of skin conductivity evidently lowers the maximum

temperature reached and this might conceivably affect the choice of material used, though the author is not competent to discuss all the issues that such a measure might involve. Moreover it must be remembered that the conductivity of materials at elevated temperatures can be very different from its value at ordinary temperatures: for most pure metals it is lower, and for alloys higher. For example all steels or ferrous substances at high temperatures tend to have about the same conductivity, though the high alloys are poor conductors in other circumstances. On the other hand, it must also be recalled that the use of special conducting material would be necessary only over the length of the order l (the characteristic length defined by equation (2)). In most examples of interest the numerical value of l is not more than a few centimetres; thus the opportunity for choice of material is probably wider than might at first sight appear. This important fact must also be remembered in many other connections.

Evidently it also pays to make the skin thickness as large as possible, again over the length affected significantly by conductivity. However, if the skin thickness d becomes appreciable compared with l we cannot expect the analysis leading to the results under consideration to remain valid, as this violates one of the simplifying assumptions of the method. This point will be returned to at a later stage, but the general conclusion is always valid that the thicker the skin, the smaller will be the temperature.

Again the emissivity of the outer surface should be made as high as possible, to radiate as much heat away as possible. This is well-known as a desirable feature of design. It equally pays to radiate heat away from the inner surface, provided it is not reflected or radiated back to it again. Now in relation to the particular wing under consideration, provided the wedge angle of the wing is not so large that the upper surface is forward-facing, the pressure on this surface will be very small, and as a result so also will be the heat input to it by kinetic heating. Thus one can afford to radiate heat to it from the underside, which is suffering severe kinetic heating. All surfaces being "black," half of the heat emitted by the inner surface of the underside is returned from the facing surface, while half is radiated away from the outer surface of the upper side. The temperature of the upper side becomes $(1/\sqrt[4]{2})$ times that of the under side, and the value of $\epsilon_i = 0{\cdot}5$. (If any of the surfaces are not "black," then $\epsilon_i < 1/2$.) We see from (3) that allowing a transfer of heat by radiation of this kind is equivalent in effect to over a threefold increase in thickness in alleviating the maximum temperature. In case it is undesirable to heat any particular part of the wing interior in this way, it would be a simple matter to provide it with a reflecting surface by way of insulation.

Even greater reductions can be obtained by projecting the underside of the wing forward of the other so that radiation from both its sides can be obtained, uninhibited by any re-emission and absorption (Fig. 1*b*); in this way with black surfaces it would be appropriate to take $\epsilon_0 = \epsilon_i = 1$. This may not appear too undesirable a modification if it is again remembered that the projection need be only of short length, to achieve the desired effect.

The only other measure open for us to adopt, to decrease the temperature, is to decrease the rate of heat transfer from the boundary layer, so far as is

possible. Now equation (4) shows that at a fixed speed of flight this means decreasing the surface pressure, or increasing the lower surface inclination (δ). For a wing of the type considered, in which the upper surface pressure will be small compared with that of the underside at extreme Mach numbers, the lift loading will be ($p_\delta \cos \delta$), whilst if the wing loading is L, say, the lift loading required for level flight is

$$L\left(1 - \frac{q_1^2}{gR}\right) = p_\delta \cos \delta \qquad .. \qquad .. \qquad .. \qquad (5)$$

R being the radius of the Earth. Hence we see that reduction of surface pressure, and so of temperature, is really a matter of reducing the wing loading.

Equations (4) and (5) together show that the angle of inclination (or incidence) of the underside may be increased with advantage provided that $[Q(\delta)/\sqrt{\cos \delta}]$ is thereby decreased. The least value of this function is probably attained for a value in excess of the angle δ required for shock-wave detachment; but as the analysis quoted is not applicable in this range, we can only say with assurance that increasing the altitude of flight, up to the highest value reconcilable with the maintenance of an attached shock at the wedge leading edge, will reduce the rate of heat transfer and so be of advantage. Such large wing incidences as are thereby involved have another advantage, in that it is possible to use quite large wedge angles for the wing section, without making any appreciable difference to the heat flux to the upper surface, which will be to all intents and purposes exposed to a near-vacuum.

To sum up, the measures to be adopted to reduce the maximum temperature are:

(i) To provide an adequate skin thickness;
(ii) To use a material of high conductivity;
(iii) To project the underside forward of the upper;

(i), (ii), (iii) over a length of the underside of the order of the characteristic length, l;

(iv) To ensure that all surfaces have a good emissivity, even if this implies allowing the upper side of the wing to be heated by the underside;

(v) To ensure that the wedge angle of the wing is not large enough to cause the upper surface pressure to be appreciable compared with that existing over the underside;

(vi) To allow flight to take place at an altitude at least as high as that compatible with the existence of an attached shock-wave at the leading-edge; and

(vii) To design the aircraft with a small wing loading.

4. Some Numerical Values

It is instructive to see how the application of the measures just discussed leads to relatively modest values of temperature rise even in the most extreme conditions of flight.

We see in fact from relations (4) and (5) that the heat transfer will be

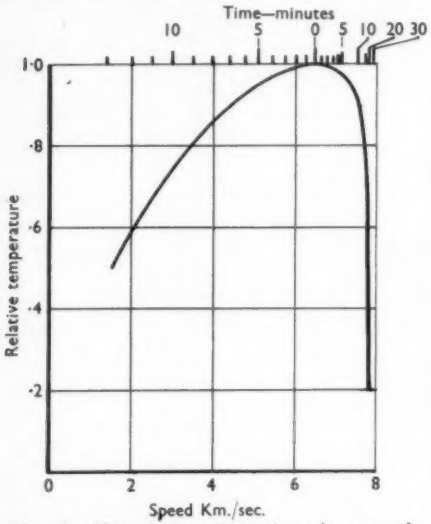

FIG. 4. Nose temperature at various speeds relative to T_{max} (achieved at 6·5 km./sec.).

highest at the speed at which

$$q_1^2\left(1-\frac{q_1^2}{gR}\right)^{1/2}$$

is maximum, i.e. at $q_1^2 = 2/3\,gR$. This corresponds to 6·5 km./sec., and might typically imply a flight Mach number of about 20. The relative reduction in nose temperature at other speeds, supposing that the altitude is adjusted to give a constant lift coefficient, is shown in Fig. 4.

We take the incidence as being that giving a maximum deflection shock at these extreme speeds, so that from (4) and (5), in dimensional terms,

$$Q_{max} = 6{\cdot}85\,L_m^{1/2}\ \text{kw/m}^{3/2}$$
(L_m in kg./sq.m.) . . . . (6)

The altitude giving this rate of heat transfer will be such that the lift coefficient equals 1·23 and the dynamic head is 0·271 times the wing loading. Thus if the wing loading were 100 kg./sq. m. (20·5 lb./sq. ft.), the indicated air speed would be only 20 metres/sec. (45 m.p.h.). The relative air density would be about 10^{-5}, implying a height in the region of 80 km. (50 miles). The structural advantages resulting from a flight path restrained to employ such low indicated air speeds, need no amplification.

Assuming the underside surface projects forward of the upper one, and all surfaces are black (so that $\epsilon_0 = \epsilon_l = 1$), we have from (6), in (3), that at this critical speed the nose temperature reaches its highest value of

$$T_{max} = 624\left(\frac{L^2_m}{k_m d_m}\right)^{1/13}\ ^\circ\text{C. absolute} \quad . . \quad . . \quad (7)$$

where L_m is in kg./sq. m. as before, k_m is in cals./cm. sec. ° C., and d_m in cms. An alinement chart for a rapid interpretation of this result is given in Fig. 5. From this one may quickly be persuaded that nose temperatures in this, the most extreme condition of flight likely to be encountered, can still be of reasonable proportions. Figures of around 1,000° C. are all that need be involved. Remember, too, that these figures are probably based on a pessimistic estimate of the heat transfer in the neighbourhood of the nose.

One reservation must be made at this stage, however. It will be recalled that the above result has been obtained on the assumption that (d/l) is small. A few specimen exact calculations (for a projecting lip bevelled at the nose to form a wedge, as shown in Fig. 1*c*) have indicated that where the value of d/l is

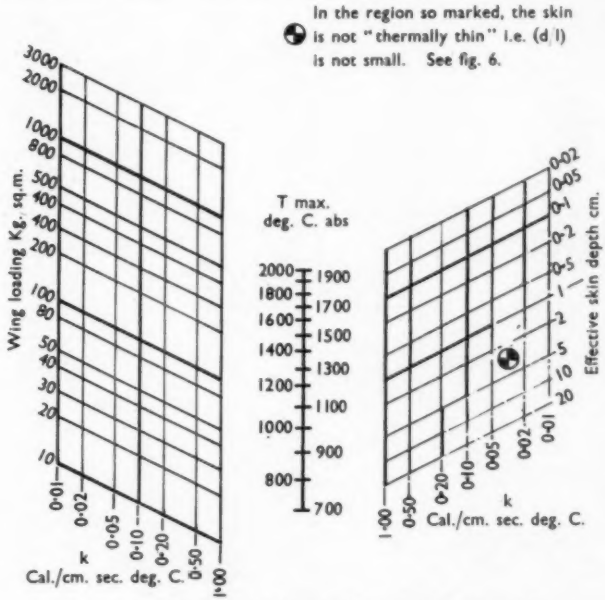

FIG. 5. Alignment to determine T_{max} from K, L and δ.

about unity, the actual nose temperature is higher, by nearly 15 per cent., than that which would be predicted by (7). This may not sound too serious an error until it is realized that, to obtain the correct answer by equation (7), we should have to substitute in place of d_m a figure for the "effective" skin thickness which is only one-fifth of the actual thickness. Greater skin thicknesses than l appear to produce little or no further reduction in temperature, so that the effective skin thickness is never likely to exceed $0.2l$, no matter how thick the skin is made.

In view of this it is safer in practice to use the relation obtained from equations (2), (3) and (6),

$$T_{max} = 1{\cdot}15\left[\frac{Q^2_{max}}{(\epsilon_0 + \epsilon_i)\sigma k(d/l)}\right]^{1/5}$$

$$= 288\left[\frac{L_m}{k_m(d/l)}\right]^{1/5} {}^\circ\text{C. absolute}$$

which gives T_{max} in terms of an effective value of d/l rather than d. A nomogram to interpret maximum temperatures on this basis is given in Fig. 6. The chart of Fig. 5 may then subsequently be used to determine d, and so also l, relevant to the initial choice of (d/l). But it will be appreciated that the value of d so found is an "*effective*" thickness, and the *actual* skin thickness required will be considerably larger if the initial value of (d/l) has been chosen as around 0·1.

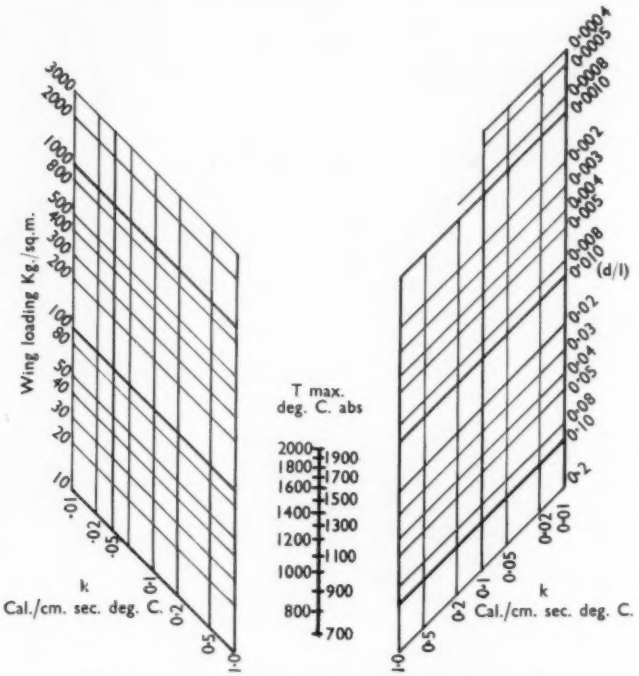

FIG. 6. Alignment to determine d/l from T_{max}, K and L.

In many structural considerations, the temperature gradient and the duration of time during which severe heating occurs are of interest. From equations (1) and (2) and by references to Fig. 2, it is possible to show that the maximum temperature gradient is

$$\left(\frac{\partial T}{\partial x}\right)_{max} = 0{\cdot}11\,\frac{T_{max}}{l}$$

and those measures which reduce the nose temperature will also reduce the temperature gradient. So far as the duration of the period of high temperature is concerned, it all depends on the flight plan. A time scale is suggested in Fig. 4 for a glide path at constant lift coefficient. Once again an advantage of using a high incidence appears, this time in that the L/D ratio being low, a relatively rapid deceleration is achieved.

Conclusions

(i) The actual rate of heat transfer to the surface at the nose of a wedge wing may well be finite; but even if it is assumed to go to infinity (like $1/\sqrt{t}$) as predicted by boundary layer theories, then the actual surface temperature is considerably below the thermometer temperature at the nose, due to conduction of heat along and within the skin.

(ii) Equations (3) and (4) of the main text together enable the temperature at the nose of the wing to be estimated at high-flight speeds.

(iii) The temperature at the nose is the maximum reached by the surface; higher values might be reached if turbulent flow existed, but this seems unlikely due to the stablizing effect of the high rates of heat transfer on the laminar flow.

(iv) Certain measures which reduce the maximum temperature reached by the surface (at the nose) are detailed in section 3, and summarized at the end of this section.

(v) The nose temperature will reach its highest value at a speed $\sqrt{2/3}$ times the circling velocity (i.e. at 6·5 km./sec.). The minimum temperature at other speeds of flight is shown in Fig. 4.

(vi) For flight at this speed, charts are given in Figs. 5 and 6 to enable the maximum temperature to be determined. The temperatures involved need only to be around about 1,000° C. if appropriate but not unreasonable measures are taken to ensure this.

(vii) In section 4 it is noted that there is a limit to the reduction which can be made to the nose temperature by increasing the skin thickness.

(viii) The above conclusions are based on a neglect of dissociation, and its presence will affect the shock wave conditions and the boundary layer heat transfer properties. In at least the latter connection there appears at the moment to be no adequate way of taking it into account.

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TECHNICAL SESSIONS AT THE ROME CONGRESS

By A. E. Slater, M.A., M.R.C.S., L.R.C.P., F.R.Met.S.

At the Seventh International Astronautical Congress in Rome (September, 1956), more than forty technical and scientific papers were read in the two morning and three afternoon sessions available, though with three-hour breaks for lunch. This allowed 15 minutes per paper in the time-table with an hour for discussion at the end of each session, but as nearly every reader overstepped his time limit, usually by a large margin, there was scarcely any time left for discussion, and so this account must be confined merely to the contents of the papers. Moreover, as no pre-prints or abstracts were available for several of the papers and the present writer was obliged to miss some of the verbal expositions, they have had to be omitted from this report. The papers presented were, as usual, of unequal merit, and some deserve fuller treatment than others. It has been thought best to group them under broad headings rather than deal with them in time-table order.

Space Voyages

Papers which come conveniently under this heading cover a wide field and range from visiting the far confines of the Universe (if any) to returning through the Earth's atmosphere. Dr. Sänger's rather startling calculations on the feasibility of long-range interstellar travel—including *internebular* journeys—were to some extent anticipated by Professor Crocco in his speech at the opening ceremony. But when Crocco asserted that, owing to "time expansion," centuries would pass by on Earth while the interstellar crews would "never grow old," and that after the ship's fuel has gone "their immortality will cease," one had to bear in mind Sänger's warning that in this kind of territory words are apt to lose their normal physical meaning.

The papers by H. R. J. Grosch, T. R. Nonweiler and M. Dubin are included under this heading because, although they deal with satellite vehicles according to their titles, they apply also to interplanetary travel in general.

One-Year Exploration Trip, Earth-Mars-Venus-Earth. Professor G. Crocco, President of the Italian Rocket Association, works out an elliptical course which grazes the orbit of Mars at the outer end of the ellipse and passes a little way inside the orbit of Venus at the inner end. In order that the Earth will be encountered again at the starting point, the ship must take just a year to go once round the ellipse, which must therefore have a semi-major axis equal to that of the Earth's orbit.

In order that each planet shall be passed closely, Mars must be at the far end of the ellipse when the ship gets there, whereas Venus can be encountered in either of two positions. Crocco has been told by the Brera observatory that a favourable configuration of the three planets to enable this to be done will occur in June, 1971, when Venus would be met at the first crossing-point of its orbit.

Assuming all three orbits to be in the same plane, and ignoring perturbations,

Crocco finds that from the Earth to Mars would take 113 days, from there to Venus 154 days, and back to Earth another 98 days. There is no need, he claims, to expend fuel in transferring from the plane of one orbit to that of another, because the ship can take off from the Earth (actually from a satellite orbit) in such a way as to set it on course for Mars, and each planet can be approached in such a way that the perturbations will leave the ship on the right course for the next one.

In calculating the perturbations, Crocco assumes that the ship grazes the surface of Mars (actually it would have to be the outer fringe of the atmosphere), and its course is thereby deviated 13½ degrees outwards; but it must approach Venus no nearer than 4 diameters of the planet, which will give it an inward deviation of 8 degrees, in order to arrive back at the Earth's orbit at a point where the Earth will be encountered again. Because of these deviations, the final return to the Earth's orbit will be delayed, and the whole voyage will take 13½ months. It could be shortened to 12½ months by passing Mars at a distance of one diameter and Venus at 71 diameters. As seen from the north, the ship would be overtaken by Mars on the right, but would itself overtake Venus on Venus's right (i.e. the dark side).

On the assumption of a payload of 2 tons, including three passengers, plus another 2 tons of provisions for a year, Crocco compares the resulting total payload of 4 tons with that needed for the so-called "minimum propellant consumption" voyage to Mars and back, which requires 259 days for getting there, 455 days there in a satellite orbit awaiting a suitable configuration for the return journey, and another 259 days to get back, adding up to nearly 3 years. Since the provisions for a similar ship would in this case weigh 6 tons, the total payload of 8 tons would render this not the most economical journey after all. Crocco's one-year trip, besides requiring less endurance from the crew and enabling two planets to be inspected, instead of only one, would, he calculates, use less than half as much fuel.

The Attainability of the Fixed Stars.—Dr. Eugen Sänger, of the Research Institute for the Physics of Reaction Propulsion at Stuttgart, shows that, according to the laws of relativistic mechanics, it should be possible for a space traveller within his own lifetime to reach any part of the universe, whereas according to "classical" mechanics, even if his speed approached that of light, the most he could do would be to visit the nearer stars a few tens of light-years away.

The reason is that, as stated in Einstein's Special Theory of Relativity, time passes more slowly for a traveller in motion than for a stationary observer, and this slowing of time becomes pronounced as the speed of light is approached. The proposed but still hypothetical photon rockets, which expel photons at the speed of light, would be able to attain comparable speeds and make interstellar journeys reasonably short. But it has hitherto not been appreciated how short such journeys can really be on the traveller's own reckoning, owing to this "time dilatation" postulated by relativity.

Sänger considers a ship carrying a chronometer and an accelerometer. As it

goes on accelerating, its speed as calculated from these two instruments continues to increase until eventually it exceeds the velocity of light, perhaps by many times, although to a "stationary" observer on the Earth the ship merely approaches the velocity of light but never reaches it. To take an example, when the traveller has attained a speed 18 times as fast as that of light, on his own reckoning, one second of his time will appear to the stationary observer as one year; at a speed 32 times that of light, a million years will pass by on the Earth for every second of the traveller's time.

As the passage of time becomes slowed down, so do the distances being covered by the traveller appear to him to become shortened in the same proportion; thus, to anyone passing by at 19 times the velocity of light, the distance of the Earth from the Sun will appear to be one kilometre. At 32 times light velocity, one kilometre will be the apparent distance from the Sun to the nearest star, Proxima Centauri.

An important corollary of these ideas, Sänger points out, is that the rate of fuel consumption will appear to the traveller to remain unaltered, reckoning in his own time units, so that to an earthly observer the rate will appear to have slowed down. On the assumption that the ship will accelerate during the first half of a voyage and then decelerate at the same rate, Sänger makes some interesting calculations, taking the acceleration due to the motor as equal to g (actually a fraction more, as he adopts the round figure of 10 m/sec.^{2} instead of 9·81), and—a rather unrealistic condition—ignoring any resistance by interstellar matter.

With a motor giving this acceleration, a journey to Proxima Centauri, 4·3 light-years distant, would take 3·6 years of the traveller's time, or 6 years of earthly time, and the mass of fuel needed would be 40 times the mass of the vehicle at the end of the journey. To reach the Andromeda nebula, 750,000 light-years distant, would take 25 years of traveller's time. (It may be noted that Sänger takes the nebular distances accepted until very recently, though they have since been doubled.) And to traverse the whole Universe, a distance Sänger assumes to be 3,000 million light years, would take 41·9 years, on the traveller's reckoning, at a mean speed 720 times that of light. But, as time is measured in the Solar System, more than 3,000 million years would elapse before his return to it; consequently, as Sänger remarks, it is "more than questionable" whether he would find the Solar System still there.

Electronic Computers and Orbit Calculation.—Dr. H. R. J. Grosch, of the Aircraft Gas Turbine Division, General Electric Company, U.S.A., points out that the asteroids which passed very near the Earth shortly before the war (but not, as he alleges, closer than the Moon) were afterwards lost because calculations for predicting their course could not be done quickly enough to keep up with their fast motion across the sky. The problem of following the Vanguard satellite and future interplanetary vehicles would be even worse but for the fact that a calculation which took several days in the 1890's, and 10 or 12 hours in the 1930's, can now be performed electronically in a third of a second. Dr. Grosch, who is in charge of a large digital computing organization, even

asserts that speeds from 10 to 100 times that of the last-mentioned figure "will certainly be available within 3 or 4 years."

He does not agree with the view that space stations and vehicles of the future will conveniently carry their own computing equipment, although transistors in place of electron tubes, and magnetic cores as memory devices, are likely to reduce the size and power of computors in the next few years. The reason, he says, is the weight and bulk of the input-output equipment, such as card readers, printers, magnetic tape units and their synchronizer. However, his own computors have often worked from programmes and data transmitted over leased telephone lines, and as space vehicles will have communication equipment anyway, it can be similarly used for this purpose. Moreover, the larger and more powerful the computing equipment is, the more cheaply can it operate—provided it is given enough work to keep it busy; in fact, he has found an inverse square law to hold, such that a job costs only half as much if it can be done four times as fast. So for this reason, too, it will be advantageous to do the calculating at ground level.

Dr. Grosch suggests a new way of computing satellite orbits which differs from the classical techniques, but will simplify the programming, which is the most expensive part of the operation. He describes it as "the method that nature uses," and claims that machines capable of using this method are already available. The "classical" workers used various means, such as approximations, to reduce the amount of calculation to the minimum possible. Dr. Grosch's new method may involve a hundred times as much calculation as the old, but the computing machine can take this in its stride. His method is to integrate numerically, using very short time intervals, taking account of all perturbing effects and their changes, such as air density (allowing if necessary for atmospheric conditions prevailing at the time at various levels), and the weakening of gravity with distance (allowing if necessary for terrestrial gravitational anomalies as well as the attractions of the Moon and Sun), at each stage.

Dr. Grosch concludes: "Awareness of computer capabilities, a fairly imaginative transformation of techniques to make economical use of these very expensive tools, and the systematic planning and programming of the work are the only things lacking for successful accomplishment of the mathematical and astronomical tasks involved in following our space stations and spaceships among the stars."

Chemical Analysis of Microscopic Spherules, Presumably of Cosmic Origin, Found in Deep-Sea Sediments.—Prof. F. Hecht and R. Patzak, of the Chemical Institute of Vienna University, found that the tiny particles mentioned in their title contain iron and nickel in the same proportion as is found in iron meteorites. Since these particles occur in sediments which have been accumulating throughout Tertiary times at least (that is, for some 60 million years), it follows that the present amount of meteoric matter in space, which is of such concern in astronautics, is not just a temporary phenomenon due to the Solar System passing through a localized interstellar cloud. The authors suggest, however, that careful examination of deep-sea deposits, which in the Pacific Ocean

accumulate at about one millimetre per thousand years, would show whether such meteoric matter has varied in amount during the past. In particular, they hope that the International Geophysical Year will bring forth an estimate of meteoric matter now falling on the Earth which is accurate enough for comparison with the past.

Interplanetary Matter and the Earth Satellite.—M. Dubin, of the Air Force Cambridge Research Centre, U.S.A., included asteroids, meteoric particles in cometary orbits, and the cosmic dust of the Zodiacal light in his "matter," and estimated that 50,000 to 50,000,000 kilograms of it fell on the Earth each day. He produced a slide showing the impact of small meteorites recorded by an Aerobee rocket; there were two at an interval of 0·08 second. As to telemetering such impacts to ground stations, he said that a meteorite of visual magnitude 20 to 25, impinging at satellite velocity, would give a 2-volt signal, and 0·1 volt was the lower limit of transmissible signals.

Earth Satellites

Papers under this heading cover proposals ranging from the "minimum" Vanguard project now under way to the elaborate residential establishment planned (but no more than planned) by Mr. Romick; fortunately, however, most of them deal with the first of these two extremes and so are of more immediate practical interest.

At a Press conference laid on by the Public Relations Office of the United States Office of Naval Research, Mrs. P. G. Conwell and others answered (or in some cases parried) a variety of questions about the Vanguard satellite and its implications. Here are some examples:—

What about Space Law? *None exists.*—If the vehicle crashes into another State, what are you going to do about it? *The probabilities of falling on another State are rather slim.*—Has the Office of Naval Research considered it? *No, this is beyond our technical programme.*

In 1951 a project not unlike this was put forward by the British Interplanetary Society; did you derive any help from this? *We have derived help from anywhere on rocketry in the world, but cannot say what help in this particular instance.*

What instruments will the satellite carry? *Radio tracking, so that we may know where it is. If we are successful, there will be several different kinds (of satellite), but we do hope for more information on cosmic radiation, and atmospheric temperature and density. Other subjects are micro-meteorites, the magnetic field and solar radiations. The instruments will be smaller than anything of the kind ever made.* (Some "transistorized" specimens, though not those to be actually used, were handed round, and they were indeed tiny).—Can the radio messages be heard by any nation? *Yes; it will be on about 100 megacycles, and any suitable antenna can be used, the larger the better.*

Is not the Department concerned at the lack of news about the Russian satellite? *They have announced that their satellite programme will be made known; these things do take time to prepare.*

Are the scientists sure that three steps will do, or if four may be necessary

later? *Calculations and experiments show that three should be enough.*—If no satellite gets into an orbit by the end of the International Geophysical Year, who would carry the responsibility? Fred Durant, the retiring I.A.F. president, answered that *there may be mishaps, but eventual success is certain. The cost will be 25–28 million dollars.* How many satellites? *We have now twelve launching vehicles. We have not started testing flights, but a Viking 13 will be used as a test vehicle by the Martin Co., first at their own place and then in Florida. No date has been fixed for the launching.*

Finally: *it is not a military project.*

The Vanguard Satellite Launching Vehicle.—N. E. Felt described the three stages by which an artificial satellite, weighing 21½ lb., in the shape of a hollow magnesium sphere of 20 in. diameter, will be launched at 300 miles altitude into an orbit round the Earth during the International Geophysical Year.

The first or bottom stage, built by the Martin Co. of Baltimore, and with motor by the General Electric Co., will be 44 ft. long, with liquid oxygen and petrol as propellants, helium to pressurize the tanks that contain them, and hydrogen peroxide which will be decomposed to provide high-temperature steam for driving the turbine that powers the propellant feed pumps. This stage will accelerate the whole vehicle to 5,500 ft./sec. and then drop off from a height of 36 miles into the sea, 275 miles from its launching point in Florida.

At the moment of detachment of the first stage, the second stage, 31 ft. long, will come into action. Designed and built by the Aerojet-General Corporation of Azuza, California, it also uses liquid propellants—white fuming nitric acid and unsymmetrical dimethyl hydrazine; they will be forced into the combustion chamber, not by pumps but by high pressure in the tanks, effected with helium. On reaching 13,400 ft./sec. at 140 miles altitude, this motor will stop and a nose cone enclosing the satellite will drop off, but the second and third stages will remain together until their momentum has taken them up to 300 miles, whereupon the second will fall off and leave the third travelling horizontally.

The third stage, a solid propellant rocket, will then be set spinning around its longitudinal axis by small solid rockets, and will be accelerated to a speed of 26,000 ft/sec., enough to maintain it in an orbit; evidently it is not expected to lose much height during this process. When the final speed is reached, the actual satellite and the third-stage rocket will become detached from each other, but there is no mention of any active means of separating them.

As to directional control, there will be no fins—in fact, it is believed that no large rocket has ever before been flown without them. Instead, the combustion chambers of both the first and second stages will be mounted on gimbals, and both will be controlled by a three-axis gyro reference system installed in the second stage. Nevertheless, some inaccuracy is expected in both the speed and direction of launch of the satellite.

For a perfect circular orbit at 300 miles altitude the velocity need only be 25,025 ft./sec., and the extra velocity given to the satellite in order to take care of these uncertainties should put it into an elliptical orbit. This ellipse must bring the satellite no nearer the Earth than 200 miles, and at the other

extreme no further than 1,400 miles. To ensure this, the greatest allowable errors are 2½ degrees upwards or downwards in direction and plus or minus 340 m.p.h. (500 ft./sec.) in speed at the moment the satellite is freed.

Mr. Felt finally gives a table comparing the Vanguard three-stage rocket and the well-known Viking on which the first stage of the Vanguard is largely modelled.

	Vanguard	*Viking*
Length	72 ft.	45 ft.
Diameter, maximum	45 ins.	45 ins.
Take-off gross weight	22,600 lb.	15,000 lb.
Velocity, maximum	25,000 ft./sec.	6,100 ft./sec.
Altitude at burnout	300 miles	40 miles
Altitude, maximum	1,400 miles	158 miles

(It may be of interest here to compare the "Absolute Minimum Orbital Vehicle" worked out by K. W. Gatland, A. M. Kunesch and A. E. Dixon in a paper given to the I.A.F. Congress of 1951 in London:—length, 51 ft.; max. diameter, 74 in.; take-off weight, 36,000 lb.; height of orbit, 500 miles.)

A Method of Launching Artificial Satellites.—Aurelio C. Robotti, of Turin, points out that if space rockets could take off from the Earth's highest mountains, much of the atmospheric resistance could be avoided and lower mass ratios could be used. Launchings from still greater altitudes could be made by using balloons or aeroplanes to carry the rocket aloft.

The author proposes using a modification of the A-4 (V-2) for the lower step and a WAC-Corporal 5 for the upper one—the same combination which resulted in a record height of 242 miles being reached over White Sands, New Mexico, in 1949. This would be taken up by an American Convair F-102A, a delta-winged type, to 14,000 m. (46,000 ft.).

The F-102A has a span of 11·6 m. (38 ft.), length 19·5 m. (64 ft.), weight without armaments 11,000 kg. (24,250 lb.), maximum speed 1,500 km./hr. (932 m.p.h.) at 11,000 m. (36,000 ft.), and ceiling 18,000 m. (59,000 ft.).

The lower rocket step has a length of 14 m. (46 ft.), maximum diameter 1·65 m. (5·4 ft.), launching weight 11,935 kg. (26,301 lb.); and the upper step, WAC-Corporal, length 4·9 m. (16 ft.), maximum diameter 0·3 m. (10 ft.), and launching weight 310 kg. (683 lb.).

However, it is not enough to add these three weights together to get the launching weight of the whole combination. Since the aircraft cannot point vertically upwards when at its ceiling, the rocket will have to be launched horizontally and then guided upwards; so the author gives it a delta wing of 9 m. length and 9 m. span (29·5 ft.), with most of the WAC-Corporal jutting out in front. Then it must hang below the aeroplane, which it does from a pair of vertical panels, their surfaces parallel to the airstream; each is attached to the A-4 at mid-span of each half wing. These panels weigh 500 kg., so the all-up weight is 23,800 kg.

The winged A-4 rests on a six-wheeled launching carriage which is fitted with JATO (assisted take-off) rockets to help the whole contraption to get up flying speed. Further to assist take-off, the A-4's tanks are at first empty, and

are later filled from another aircraft; a drawing shows the refuelling tube attached to the Convair's nose, from which the fluid passes to the A-4's tanks through the vertical panels which join the two craft. Since the two-step rocket weighs only 2,500 kg. empty, the total take-off weight is only 14,000 kg. (31,000 lb.).

On reaching the ceiling of the whole combination at 14 km. (8·7 miles or 46,000 ft.), with a "residual velocity" of 150 m./sec. (336 m.p.h.), the Convair pilot drops the two-step rocket and guides it on its course by radio; it then discards the vertical panels. This, unfortunately, is as far as the author takes us; he says nothing about the A-4 discarding its wing—nor about the need for the WAC to carry a third rocket step, for it could not itself reach circular velocity, according to performance figures worked out in an appendix and shown in his Fig. 2.

If the A-4-WAC combination starts from ground level, this diagrams shows, the A-4 burns out at 32 km. going at 1,225 m./sec., then the WAC-Corporal burns out at 91 km. going at 2,235 m./sec., and coasts on up to 390 km. (242 miles). The author calculates that, if both are launched together from 14 km., then the A-4 burns out at 59·6 km. going at 1,856 m./sec., and the WAC-Corporal burns out at 158·5 km. (98·5 miles) going at 2,740 m./sec. (8,470 ft./sec.) and coasts vertically up to 587 km. (364 miles).

The Effect of the Earth's Oblateness and Atmosphere on a Satellite Orbit.—John De Nike, of the Advanced Design Department of the Glenn L. Martin Co., explains that the Company is not only interested in the rocket vehicle it is producing to launch the Vanguard satellite, but also in the control accuracy requirements; these are related to guidance and tracking accuracy, so the satellite's orbit needs to be analysed.

The simplest satellite orbit would be an exact circle round a perfectly spherical Earth in a complete vacuum. But in calculating the possible orbits expected, a digital computor had to be used to solve the various equations dealing with atmospheric drag and the effects of the Earth's oblateness (equatorial diameter greater than polar diameter). The effect of the latter condition varies according to the inclination of the satellite's orbit to the equator, and the computor was given ten different inclinations, from zero to 90°, to deal with. Four different drag functions, ranging from 0 to 7·12 sq. ft. per slug, were used, and a range of four launching heights from 150 to 300 miles, while various ellipticities, due to variations in launching velocity, were assumed.

Mr. De Nike gives the results from one example in which the orbit was assumed to be inclined 83° to the equator, the drag function was 1.80, and the height of the satellite was 300 miles at its nearest point to the Earth (perigee) and 317 miles at its furthest point (apogee).

The computor showed that the rate of loss of perigee height, due to atmospheric drag, would average 195 ft./day, but that, owing to the Earth's oblateness, there is a large oscillation in height with a period of 41 days, such that a loss of about 17,000 ft. in 23 days is followed by a gain of about 9,000 ft. in the next 18 days. The height of apogee oscillates in step with perigee, but

its average rate of reduction is greater at about 250 ft./ day, so that the elliptical orbit would become gradually more circular.

The Earth's oblateness would also cause displacements of perigee and apogee in both latitude and longitude. Over a period of about 82 days, starting with apogee and perigee at a latitude of 83° north and south respectively, each point would cross the equator to latitude 83° on the other side and then return across the equator to its original position; they are at their extremes of latitude just when their altitude oscillations bring them nearest the Earth, which means that the greatest loss of altitude of the satellite occurs when perigee is at the highest latitude—a most important conclusion.

In the same period of 82 days, each point changes its longitude, as it would be measured on a non-rotating Earth, through a complete cycle of 360°. All these variations are going to complicate the problem of using the satellite's orbit to determine the geophysical properties of the Earth.

Mr. De Nike also mentions the results of another of the tasks given to the computor; it had the same data as before, except that the launch was at less than circular velocity, so that apogee, at the point of launch, was 300 miles high, and perigee only 170 miles. The same oscillations appeared as before, though their period was reduced from 41 to 38 days; but the apogee height was lowered at an average of about 6,000 ft./day instead of only 250 ft.

As the author points out, these calculations are based on standard values now accepted for the geophysical properties of the Earth. When the satellite goes into action, we shall find out to what extent these standard values are incorrect.

Satellite Librations.—Dr. Wolfgang, B. Klemperer and Robert M. L. Baker, junr., of the Douglas Aircraft Co., point out that, if two massive objects were released inside the cabin of a manned satellite, one nearer the Earth than the other, they would begin to drift apart because they would follow different orbits which would cause their separation to become a maximum on the opposite side of the Earth; the one nearer the Earth would also cover its orbit at greater average speed. If now the two masses are joined by a rod, their attempt to separate would, the authors say, bring the rod joining them into a vertical position (with respect to the Earth), and if it was deflected from this position it would thereafter oscillate about it, rather like a pendulum. If the weight of the rod is neglected, the number of complete swings made by this body during each revolution round the Earth works out at 1·73 (the square root of 3); i.e., one such swing back and forth would take 52 minutes for a satellite circling the Earth in 90 minutes.

Supposing that, instead of being dumb-bell-shaped as described, the satellite body is a nearly round spheroid, the number of oscillations per revolution is the square root of $1\frac{1}{2}$. It follows that any oblong satellite will take up a position with its long axis vertical, and will oscillate about this position if disturbed.

The authors, having established this phenomenon, go on to discuss whether it could be made use of to help in navigating a space vehicle, such as by building it in the shape of a dumb-bell and putting ultra-sensitive strain gauges on the connecting rod. They would register zero with the dumb-bell horizontal and some average tension when it was vertical, but although this would show which

direction was vertical, it would still be impossible to distinguish up from down or, likewise, east from west (i.e., fore from aft). If, instead of using strain gauges, two, three or four objects were released in the cabin, the same limitation would apply. What with the extremely small forces or motions to be measured, and their possible masking by oscillations of the cabin and movements of its other contents, the authors say, "how to sense the direction to the nearest gravitational centre remains a very elusive problem."

Temperature Problems of Satellites.—Prof. S. F. Singer wrote this paper in conjunction with D. T. Goldman as Part 4 of a series "Studies of a Minimum Orbital Unmanned Satellite of the Earth (MOUSE)," this part being entitled "Radiation Equilibrium and Temperature" in the printed version. Both authors are at the University of Maryland, U.S.A., and Prof. Singer has been for several years a foremost advocate of an artificial satellite for physical research.

The object of this paper is to enable any designer of a satellite to see at once, from the nomograms provided, what its temperature is likely to be. The impinging of cosmic particles or meteoric matter, or of the atmosphere at any height above 50 or 60 km, adds such a minute amount of heat to a satellite that their effects can be neglected, and only radiation inwards and outwards need be considered, apart from conduction of heat from one part of the satellite to another, which can be assumed to be instantaneous if the satellite is small and spherical.

The biggest source of heat is direct radiation from the Sun, though this is cut off during the period when the satellite is in the Earth's shadow; the more the plane of its orbit is inclined to the direction of the Sun, or the higher it is above the Earth, the shorter this period becomes. Radiation from the Earth is the other main source, and varies according to the cloudiness and the temperature of the Earth's surface, which in turn varies with latitude and according to the time of day. The satellite, in turn, radiates heat away into space.

The authors work out one example from the balance of these radiations; assuming the Earth to have its average temperature of 14° C. and average albedo (proportion of radiation reflected back) of 0·34, and the satellite to have a visual albedo of 0·9 and an infra-red emissivity of 95 per cent., and to be circling the equator at a height of 200 miles, then the temperature of the satellite comes out at 189·5° K., which is 83·5° below zero on the Centigrade scale.

As to the satellite generating internal heat, for instance by its power supply, the authors find that its influence is unimportant so long as the heat generated per unit area of the satellite's surface is less than the input of energy from the Sun. This means in practice that, if much heat is generated inside the satellite, its diameter should be increased to the point where the amount of generated heat per square metre of surface is kept down to 1,000 watts; however, if the diameter is increased still more, the heat input from the Sun will go on increasing, which may be undesirable.

If the satellite has no spin, so that half of its surface only is ever in sunlight, conduction of heat to the dark side is very large compared with heat received

from the Sun—unless, in the case of a large satellite, conduction of heat can only take place along its skin. On the other hand, if the satellite has a nuclear power supply at a very much higher temperature than that at which the rest of its equipment can operate, then it may have to be separated into two portions; here again, their distance apart should be such that the energy radiated from one to the other is of the same order of magnitude as that received from the Sun.

An Engineering Approach to a Minimum Weight Design of Orbital Ferry Vehicles.—Björn Bergqvist, research director of the Swedish Interplanetary Society, described the work of a "project study team" on the most economical method of taking up stores to an assumed "manned space platform," weighing hundreds of tons, circling the Earth at a height of 1,000 km. (621 miles). For ferrying up to the orbit from the Earth, both crew rockets and crewless freight rockets will be needed, and as the latter are of most economic importance, it is these which have been studied by the team.

These freight rockets are given a payload of only 1 ton each, so that series manufacturing methods can be used. Rather unexpectedly, the team found that it would be cheaper not to recover the steps of the launching rocket; this was mainly because of the long time taken in recovery, the trouble of making them fit for re-use, and the added weight of the wings and parachutes they would need. As it is, the rockets would not even need fins, as their motors would be pivoted in their gimbals for directional control. It is assumed that the accuracy of this form of control will be improved in future as a result of experience with the Vanguard; otherwise, present-day technical knowledge is assumed in the design of the rockets. Calculations by the team show that "the thermal stresses are by far the determining stresses in the outer shell structure," so an insulating ceramic lacquer on the hull and a honeycomb hexagonal core for the walls are proposed.

Other calculations have shown that the use of fewer steps, to reduce the functional complexity, is not such a disadvantage as had been thought; in fact, in certain conditions three steps give a lower launching weight than four steps.

Concept for a Manned Earth Satellite Terminal Evolving from Earth-to-Orbit Ferry Rockets.—Darrell Romick, who chose his title so that the initials of the principal words would spell METEOR, had persuaded his firm, the Goodyear Aircraft Corporation, to sponsor his scheme with an elegant illustrated brochure of 60 pages, a whole centimetre thick, depicting on its cover a huge space station with the words "MANEUVER CAREFULLY" painted on its landing-stage end.

Its basic building unit is to be the framework of the top step of a three-stage rocket; the lower two steps, each with a delta wing, will be piloted back to Earth as gliders, then fitted temporarily with jet engines so that they can be flown back to base, and used again. The first step has 51 rocket motor units, and the second 9 units, each of 500,000 lb. thrust; their launching weights are 9,000 and 1,250 tons respectively, and that of the third step 140 tons, reducing to 53 tons on arrival at the orbit.

The station is to start functioning usefully soon after its construction is

begun, after which it will be gradually extended. First, a number of third-step frames will be joined end-to-end, their tanks filled with a store of air. They will form a tube of 9 ft. diameter, round which a cylinder of 75 ft. diameter is built up; this is rounded at one end, which contains docking facilities for spaceships, while the other end serves as a hub for a wheel of 500 ft. diameter, which contains living accommodation and rotates to provide a substitute for gravity.

Eventually this structure is to be enlarged until the cylinder's diameter is 1,000 feet, that of the wheel 1,500 ft., and the whole "satellite terminal" has a length of 3,000 ft. The wheel by this time will include such amenities as a gymnasium, theatres and churches (both in the plural); in fact, the author says, "life on the terminal can be made surprisingly similar to that on the Earth." (What play could not a cynic make with this statement!) All non-residential activities, on the other hand, will be carried on in the non-rotating cylinder, including shipbuilding: small spaceships can be built inside, and larger ones made in sections and assembled outside.

Finally, the author produces a time-table: the station, in its initial form, is to start operating towards the end of 1971.

Moon Rockets

Four papers came under this heading, as judged from their titles, but of only one, Dr. Buchheim's, was a pre-print in English available. Fortunately, this one was of considerable importance, as it really got down in detail to the technique of establishing a lunar satellite in its orbit, and this may well be the next step from the Earth satellite out into space—though still not a human step.

Artificial Satellites of the Moon.—Dr. Robert W. Buchheim, on behalf of the RAND Corporation of Santa Monica, California, has tackled the problem of establishing a small satellite, carrying instruments, in an orbit round the Moon. But it is not possible by analytical methods to work out how to limit such an orbit between the extremes of hitting the Moon on the one hand, and being recaptured by the Earth on the other. The only way was to use the firm's digital computor JOHNNIAC, giving it a selection of horizontal launching velocities at a range of heights between 500 and 2,500 miles above the Moon's surface, in the plane of the Moon's orbit, and setting it to work out the subsequent path of the satellite for either 10 or 20 days. The attraction of both the Moon and the Earth have to be taken into account, and even if the satellite stays in its orbit as long as that, Dr. Buchheim says, there is still no guarantee that it will do so for ever.

Incidentally, the limit beyond which a lunar satellite must not stray in order to avoid capture by the Earth is *not* the same as the "zero-gravity" point where the attractions of the Earth and Moon balance each other.

As to the preliminary journey from the Earth to the Moon, the computor shows that a satisfactory path would result if the satellite is launched from its booster at 35,100 ft./sec. (6.65 miles/sec.), 341 miles above a point on the Earth's surface 108° west of the sub-lunar point, at an angle 14·2° above the horizontal. It should then pass to the left of the Moon (as looked at from north) and arrive over a point 140·4° beyond the sub-terrestrial point, at a height of 1,000 miles

above the Moon's surface, going at 7,707 ft./sec., 2·12 days after take-off from Earth.

Buchheim has already found that the satellite's maximum permissible horizontal speed at this height above the Moon, to avoid its being recaptured by the Earth, is 5,338 ft./sec., while the minimum for avoiding collision with the Moon, allowing for a possible 5° error in direction, is 3,280 ft./sec. (for metric-minded readers, just 1 km./sec. at 1,600 km. height). The mean between these speeds, 4,309 ft./sec., is taken by him as the most desirable one for the satellite to start at in its circum-lunar orbit, so it will have to be retarded by 3,398 ft./sec. by means of a rocket—a solid-fuel one for convenience; i.e., its velocity must be nearly halved. It will then complete one revolution of the Moon in 0·2652 days (6 hr. 22 min.) as seen from the Earth.

It will be noticed that this manœuvre puts the satellite into a retrograde orbit —that is, clockwise as looked at from north. The computor showed that it would be much more difficult to put it into a direct orbit—counter-clockwise seen from north—because, if the launching speed (into its circum-lunar orbit) fell much below the maximum allowable, it would hit the opposite side of the Moon after a couple of elongated revolutions. (According to Figs. 18 to 21, if the satellite is launched at 0·9675 of the maximum permissible velocity, it settles comfortably into a direct orbit, but if launched at 0·9946 of the maximum, it falls on to the Moon; there seems something wrong here. Another point needing explanation is that, if the satellite were launched vertically away from the Moon, it would, according to Fig. 23, eventually fall back again, even if it succeeded in making a couple of revolutions first; yet the author, on page 17, says: "These results indicate the possibility of establishing a long-duration 'semi-satellite' orbit from vertical projection as well as horizontal.")

Far more accuracy will be needed to get a circum-lunar satellite into its orbit than to put the "Vanguard" into a safe orbit round the Earth. The allowable errors in launching the lunar satellite from the Earth are − 33 ft./sec. to + 77 ft./sec. in velocity, and + 0·135° to − 0·3° in angle to the horizontal, to give it a retrograde orbit round the Moon. If the expected errors in launching the "Vanguard" are multiplied by the proportion in launching speeds of the two vehicles, the results are 896 ft./sec. in velocity and 4·1° in direction, each of which is about 20 times the mean error allowable for the lunar satellite. And the allowable errors for launching it into a direct orbit are only 0·45 of those for a retrograde orbit.

These allowable departures from launching accuracy imply a possible variation of 4 hr. in the journey time to the Moon, equivalent to 7 lunar diameters, so the decelerating rocket cannot be fired by a pre-set clock; the firing must be controlled from the Earth or automatically from its position relative to the Moon. Furthermore, this rocket motor must be aligned in the right direction already on departure from the Earth. Arguing from experience with the Viking, and allowing for torque due to the gravitational field, Buchheim finds that errors in the firing direction could be kept within bounds by spinning the satellite at one or two revolutions a second during its journey.

As to its size, the author quotes an estimate that a starting weight of about 1,000,000 lb. (446 tons) would be needed to launch 500 lb. into the required

orbit; if half this (250 lb.) is accounted for by the decelerating rocket, and half the remainder by a spherical metal skin, its diameter would be 166 ft., giving it a brightness, if white, equivalent to a star of 9·5 magnitude. To see it at one lunar diameter from the bright limb of the Moon, he estimates, a 12-in. telescope would be needed.

All these calculations assume the Earth to be spherical and the Moon's orbit round it to be circular. Actually, as the author shows in an appendix, it would be necessary to take into account the Sun's gravitation, the Earth's equatorial bulge, the eccentricity of the Moon's orbit and its inclination to the Earth's equator. But the effect of the Sun's radiation pressure is, fortunately, negligible.

On a Small Lunar Rocket Vehicle.—K. R. Stehling and R. Foster, of the United States, have worked out a scheme for landing a 4-lb. payload on the Moon, either in the form of flash-powder, or of instruments designed to survive the crash. It is to be launched by a three-step assembly of solid rockets, weighing 14 tons, from a gyro-stabilized platform at 70,000 ft., to which height it will be lifted by a "Skyhook" balloon of 4,000,000 cu. ft. capacity. The whole lot will go up *through* the balloon, or perhaps a cluster of balloons; and as the expense is modest, as such expenses go, a number of "rounds" could be fired in the hope that one of them would hit the Moon. A final velocity of 37,000 ft./sec. at burn-out should get the 4-lb. vehicle past the zero-gravity point between Earth and Moon, according to Stehling, who is in charge of the Propulsion Section for Project Vanguard.

A Lunar Rocket for Observations.—Dr. Alessandro Boni, of Rome, proposed getting photographs of the other side of the Moon from a vehicle which need not cost much more than the Vanguard satellite, because the batteries for operating it need only last a very short time. He discussed the possibility of televising the pictures back to Earth, but had not worked out the instrumentation in much detail; nevertheless he thought it not impossible to have the scheme working by some time in 1958.

Rocket Technology

So many papers come under this heading that few can be described in any detail. Which few should be chosen? The more conventional ones are, no doubt, those most immediately useful, but the specialist will want to read the entire text. General readers would probably be more interested in novel and unconventional ideas, so some of these will be given more space.

On the Application of Solar Power in Space Flight.—Krafft A. Ehricke, Chief of Preliminary Design and Systems Analysis in the Astronautics Division of Convair, looks ahead to the time when the scope of astronautical expeditions will be enlarged and people will be getting dissatisfied with a supply system whereby, even with high-performance propellants such as oxygen-hydrazine, every pound of net payload will still run away with 100 lb. of propellant and 16 to 20 lb. of "hardware." He considers various methods of "energizing

expendable material" as an alternative to chemical rockets. These are: the atomic pile, which gives a moderate improvement in specific impulse; the electric arc, which has hitherto met with cooling difficulties in practice; Sänger's fusion rocket, which is still in a theoretical stage; and solar energy, which he spends the rest of the paper discussing, having thought out a workable scheme for applying it. Since these last three methods give thrusts which are small and long-continued, rather than large and brief, they are of no use for taking-off from planets, but are effective well out in space.

Solar energy being so dilute in space, will have to be collected from a large area. Large collectors mean long pipelines to carry the propellant from its storage tank to the point where the Sun's rays are focussed to heat it, and from there to the nozzle where it is expelled. Cooling devices for these pipes would use up too much extra weight, so they must be allowed to get as hot as the propellant, which may therefore not be heated to more than 1,000° K. For the propellant hydrogen is proposed, with an expansion ratio of 15/0·1 atmospheres. This means that, for every pound of thrust developed by the motor, 116 sq. ft. of collecting surface will be theoretically needed; in practice, this figure should be increased to 160 sq. ft. to allow for a reduction in the system's efficiency from various causes.

The most spectacular feature of Krafft Ehricke's scheme—at least, to the non-specialist—is his contraption for collecting sunlight. A parabolic mirror, he points out, would be much too heavy; so his collecting unit is a plastic sphere of 128 ft. diameter, made of polyethylene terephthalate 0·001 in. thick, blown up to a pressure of 0·01 lb./sq. in. (less than one-thousandth of an atmosphere), which is all it needs to keep its shape in empty space. The half of the sphere nearest the Sun would be left transparent (it has 90 per cent. transparency in visible light), while the other half would be sprayed with silver or aluminium to give it a reflecting surface.

A hemispherical reflector, of course, does not concentrate the light into a sharp focus as a parabolic one does—in fact, the outer 30° of the hemisphere brings the rays nowhere near a focus; nevertheless, the saving of weight is immense, and anyway the heater containing hydrogen is of finite size, so the focus need not be sharp. The heater will, when in action, contain at any one time enough hydrogen to keep the motor going for 13 sec. at a consumption of about 0·35 lb/sec. To start the motor, some pressure will need to be produced at the tank outlet, perhaps by displacement bodies or solid starter rockets.

Ehricke's scheme is for two spherical reflectors of the size mentioned, with everything else placed between them—the hydrogen tank, the rocket nozzle, and the crew's cabin. A common axis will go through the lot, and on this the reflectors can be turned towards or away from the Sun, being braced together with wires so as to move in unison. The tank will contain 11,000 lb. of liquid hydrogen, and the author points out that if this were a chemical rocket, an additional weight of 45,000 to 50,000 lb. of oxygen would have to be carried too. As it is, the solar reflectors and their associated fitments, which enable the oxygen to be dispensed with, weigh only 1,000 lb.; the gross weight comes out at 16,400 lb., and empty weight 5,600 lb.

As an alternative, Ehricke suggests a single sphere of 303 ft. diameter; this would give the whole vehicle a gross weight of 38,000 lb. (17 tons) and empty weight 8,500 lb. He then goes into a rather involved argument about possible ways of improving the vessel's performance, such as how to meet the consequences of a higher working temperature for the hydrogen.

Finally, there is a discussion of suitable orbits for a vehicle with such a low thrust—160 lb., giving it initially an acceleration of one-hundredth *g*. It would, of course, start from an orbit round the Earth, in which it would have been assembled. The most economical way of enlarging such an orbit, preparatory to getting away from the Earth, is to convert it into a continually elongating ellipse; this is done by applying power only when the vessel is at the end nearest the Earth (perigee), which is also the position at which supplies are most economically taken on from the Earth.

The Payload-Ratios of Small-Thrust Space-Vehicles.—M. Vertregt deals with large thrusts as well as small, in spite of his title. It is well known that, the bigger the thrust, the sooner will a rocket attain the velocity desired (whether escape velocity or circular velocity), and the smaller will be the payload ratio, which is the ratio of the initial weight of the rocket to its payload. But the exact relation between thrust and payload-ratio is very difficult to work out, and, in order to do so, Vertregt makes some simplifying assumptions such as ignoring air resistance, the gravitational pull of the Sun, etc., which are justifiable because his only object is to compare the effects of big and small thrusts.

He shows the error that arises from assuming all the thrust to be concentrated into an infinitely short period at the moment of launching, which will give a rocket mass several times too small. For instance, for vertical take-off from the Earth's surface, with a thrust giving four times as much acceleration as the deceleration due to gravity, the mass-ratio comes out at twice, and the payload-ratio two and a half times, that calculated on the assumption of "instantaneous" thrust.

For a ship already installed in a circular orbit round the Earth, Vertregt discusses the advantages of electrically-propelled rockets over chemical rockets. They are: (1) the velocity of the exhaust gases is high, therefore the mass-ratio will be low; (2) the mass of the propellant is low, which also makes for a low mass-ratio, so that in general one step will suffice; (3) the thrust is low, giving low accelerations, so that the structure can be light and the structural ratio high; but (4) the mass of the motor is high, which lowers the structure ratio. The author applies his method to a "typical electric spaceship" proposed by Ernst Stuhlinger at the 1954 I.A.F. Congress at Innsbruck, which was to be propelled by rubidium or caesium ions and electrons; he disagrees with Stuhlinger's calculations and finds that the ship would take a year to reach a velocity of 12 km./sec.!

Implications of a Recent Rocket Experiment on Possible Upper Atmospheric Propulsion Systems using Atomic Oxygen.—Jerome Pressman, of the Air Force Cambridge Research Centre, U.S.A., refers in his paper to the oxygen in the ionosphere about 60 miles up, where the molecules, normally made up of two oxygen atoms each, are disrupted into single atoms by the Sun's radiation. The

"recent experiment" was made with an Aerobee rocket, from which nitric oxide was released to promote recombination of the oxygen atoms into O_2 molecules; the process is a catalytic one, with the nitric oxide as catalyst, and the energy released by the recombination produced a glow in the sky three miles across. As fast as the single oxygen atoms re-combine, more are produced by the action of sunlight in splitting the molecules.

Pressman's idea is to make use of this type of reaction with the natural ionospheric "fuel" in a kind of ramjet with a duct of 10 m. length (33 ft.) and 10 sq. m. cross-section (108 sq. ft.), which would take in 3×10^{22} oxygen atoms per sec. and produce about 300 horse-power, travelling at Mach 20, which should make it almost a satellite by overcoming the residual drag.

(The writer is indebted to Mr. A. V. Cleaver for the above information, the text of the paper not being available. As Mr. Cleaver pointed out in *The Aeroplane* of October 5, 1956, p. 118: "This interesting suggestion was not accompanied by any discussion of the parallel skin-heating problem, but if the drag powers were only of this order, it seems probable that the heat so produced could be radiated away from the vehicle, or even utilized in another auxiliary propulsion system.")

Considerations on the Problem of Utilizing Nuclear Energy in Astronautics.—I. C. Corbetta presented his paper in Italian, and anyone unfamiliar with that language is advised to read the French version of the abstract rather than the German or English versions, which are not too correct, grammatical or comprehensible. Here is a translation of the French abstract:—

For astronautics the application of thermonuclear energy is of the greatest interest. In practice it is not possible to utilize the explosion of Uranium 235 to obtain the temperature at which one gets fusion of the isotopes of hydrogen (deuterium and tritium). In consequence, one must achieve at a single point the temperature needed to produce the reaction. Research into methods of realizing this temperature will have to be done by a specialized organization. It is desirable to set up an Institute for High Temperature Research.

A Contribution to the Theory of Steam Rockets.—H. Bednarczyk, of the Institute for General Mechanics in the Technical University of Vienna, says little about the actual structure of a steam rocket, but concentrates on a mathematical investigation of the processes going on within it, in the hope of mitigating certain snags. One of these is the delay in boiling whilst passing through the nozzle, which is combatted by dividing the water into a very fine spray with a droplet size of about a thousandth of a centimetre.

Other headings in the discussion are: "Thermodynamic conditions in the reservoir during expulsion of hot water," "The spray nozzle and a discussion of the influence of surface tension on the thermodynamic conditions," "Investigation of the 'Laval' conditions," "Nozzle design at the outer end and estimation of the losses caused by faulty design," and "Nozzle shape and evaporation rate."

Remarks on the Question of Step Rockets.—Rolf Engel, President of the Astronautical Association of Egypt, believes that in future the majority of step rockets will be flown unmanned. Liquid propellants may be most suitable for

rockets designed for carrying passengers and ascending through the atmosphere, when low accelerations are needed; but he shows that for unmanned step rockets in a vacuum, whether in a gravitational field or not, modern solid-fuel power plants may well prove more economical.

Engel adds an historical section in which he attributes the first publication of the step-rocket idea to a patent of R. H. Goddard's dated July 7, 1914; next come H. Oberth in 1923, G. Hamel in 1927, G. von Pirquet in 1928, and so on, through A. V. Cleaver in 1949 (in this *Journal*) up to D. M. Cole and L. I. Epstein in 1956.

An Acceleration Procedure with the Possibility of Eventual Utilization and Exhaustion of the Normal Propulsive Load of a Rocket.—Dr. Alberto Jona, an aeronautical project engineer, of Rome, has an idea for providing additional thrust—in effect a fourth step—for a three-step rocket, by extruding a large, thin-walled Laval reactor, and combining certain materials forming the body of the rocket to act as propellants and give a chemical reaction. He works out some figures which would result from applying the idea to the satellite vehicle design by K. W. Gatland, A. M. Kunesch and A. E. Dixon described in this *Journal* and at the London I.A.F. Congress of 1951. The "fourth step," 79 ft. long and 23 ft. wide, would take 350 minutes to use up 926 lb. of propellants, giving a thrust of 13·2 lb. and an acceleration of 0·042 *g*.

Combustion Processes and Chemical Reactions.—Dr. E. A. de Zubay, head of the Fuel Section in the Research Division of the Curtiss-Wright Corporation, New Jersey, points out that, when the conversion of chemical energy to heat energy is worked out according to thermodynamic laws, nothing is deduced about the rate at which the conversion takes place. The simplest way of introducing this "time variable" into the investigation is to assume that a homogeneous mixture of fuel and oxidant mixes instantaneously with the material in the reaction zone on entering it, a conception which is practically useful only in ramjets and idealized flameholding systems.

De Zubay proceeds from this simplified case to that of successive reactors possessing finite volume, and finds, within the limits of his examination, that judicious staging of the combustion process could lead to appreciable gains in combustor performance. He then extends his consideration to a system of infinitesimal volumes in continuous sequence, but gives a final warning that his treatment is over-simplified and would need to be extended for practical use.

The author complains that he cannot get the data he wants on oxidant-fuel mixtures, and has had to work with air-propane systems; presumably the rest is "classified."

Problems of Materials in Rocket Motors with Oscillating Combustion.—Bertwin Langenecker described experiments on metals which had been subjected to oscillatory influences between 10 and 800,000 cycles. He found, among his most important results, the effect of different oscillation-frequencies in reducing the yield point and decreasing the elasticity of the metals. These effects, together with cavitation on the metal surfaces, are believed to be responsible for

spontaneous destruction of power plants. Langenecker proposes a new method for limiting the amplitudes of unstable combustion.

On Systems with Chemically-reacting Components in Equilibrium.—H. J. Kaeppler and G. Baumann, of the Research Institute for the Physics of Reaction Propulsion in Stuttgart, give a generalized discussion for arbitrary systems with chemical reactions in equilibrium. A system of equations for an arbitrary number of components and for an arbitrary number of chemical reactions is derived and a generalized method of solution for this system is given. The application of the method is illustrated by means of examples. The generalized method can immediately be applied to actual cases of chemical reactions and is particularly suited to complicated systems.

Some considerations on the Theory of Spaceship Propulsion.—H. Ruppe, of Berlin, starts by classifying with Teutonic thoroughness all possible propulsion systems. His classification is:—

A: Motor, (1) in the vehicle, (2) not in it. B: Impulse-carrier, (1) in vehicle, (2) outside but in physical contact with it, (3) not in physical contact. C: Energy source, (1) in vehicle, (2) not in it. Trams, for instance, are A1-B2-C2, and the author gives seven possible combinations for space-flight, from A1-B1-C1 to A2-B3-C2. The latter is represented by Luigi Gussalli's proposal for bombarding a ship with a stream of dust particles shot out from the Earth and subsequently accelerated by solar radiation pressure; it was criticized by Dr. Shepherd in *J.B.I.S.* for May, 1948, p. 117.

Ruppe works out certain fundamental relationships (e.g., optimal fuel-to-payload with respect to minimal duration of journey for a given distance) for nuclear propulsion, solar radiation, and beta-ray with electric arc heating—all under the simplifying assumption that the vehicle is unaffected by outside forces—and compares them with the values for chemical rockets.

On a Possible Method of Increasing the Exhaust Velocity of a Rocket Propulsion System.—Dr. Walter Peschka, of the Technical University of Vienna, proposes a method analagous to film cooling, for enabling higher temperatures to be used in the combustion chamber. In connection with this, he deals with the expansion of hydrogen through a nozzle, assuming dissociation equilibrium to be maintained; and he derives an approximate approach which allows the flow of any compressible frictionless fluid to be calculated if the Mach number of the flow in at least two points is given. His method may be applied in cases of multi-dimensional flow.

Space Law

Under this heading we have few papers but a wide range—all the way from Andrew Haley's pacific humanitarianism (if that is still the correct word where a multiplicity of intelligent species are concerned) to Fredrico Robotti's belligerency (involving only the human species, fortunately for the others). As the latter paper came over in translation through the headphones, some delegates became more and more horrified as they remembered the I.A.F.

pledge to develop space-flight for peaceful purposes only; still, it should presumably find a place in this section, even if the only law it illustrates is that of the jungle.

Mr. Haley's paper has the makings of a classic, even if it invites criticism in one respect. It is true, as he appears to be the first to point out, that when we get out into space the "Golden Rule" of anthropocentric law could harm those to whom it is applied. But is it not equally true that his "Great Rule of Metalaw" could, in some circumstances, prove most unpleasant to those who apply it?

Space Law and Metalaw: A Synoptic View.—Andrew G. Haley, Attorney-at-Law and Chairman of the American Rocket Society, contrasts anthropocentric law, which deals with human relationships, with "metalaw"—a term which he does not exactly define, but it evidently means a body of law which will have to come into existence when space-travel begins and will regulate, among other things, the relationships between the travellers and any intelligent beings they may encounter on other worlds.

Haley gives many variants, from great authorities of the past, of the Golden Rule of anthropocentric law: "Do unto others as you would have them do unto you." But, he points out, if this rule were applied to sapient beings differing in kind from ourselves, it might lead to their destruction; examples of possible destructive agents are the various electro-magnetic waves and pressure waves (sound) which we use for communication, or infective germs, or even, he suggests, telepathy. So he enunciates the Great Rule of Metalaw: "Do unto others as they would have you do unto them." And he would apply this rule so strictly that: "in any instance where there is reason to believe that life exists on a planet, no Earth spaceship may land without having satisfactorily ascertained that (1) the landing and contact will injure neither the explorer nor the explored; and, (2) until the Earth ship has been invited to land by the explored." To those who would raise objections about the difficulties of intelligible communication with such entirely different organisms, Haley answers that "the regulation must be adhered to without exception, or we will project into space the bleak and devastating geocentric crimes of mankind."

The author quotes an estimate by Colonel W. Davis in a paper, "Fundamental Basis of Space Flight," which was circulated to the delegates but not included in the programme, that manned space-flight may come much sooner than expected, and that "our usual estimate of 25 to 50 years before man's first flight to the planets is probably much too conservative." Another good reason for raising the question of space law now is that high-altitude rockets and the imminent prospect of artificial satellites have already outdated the so-called "international law" relating to air space; in fact, Haley states, "This law is not international—it is a hodge-podge of strong laws of individual nations which assert absolute sovereignty over air space." The satellites may violate the municipal law of half a dozen nations, he says, and they will be legally possible "for the sole reason that no nation has voiced objection."

As to international law, Haley gives an erudite discussion of the rival conceptions of "positive law," which is enacted by governments, and "natural

law," first conceived by Francisco de Vitoria in Spain as a "system of rules and principles for the guidance of human conduct which . . . might be discovered by the rational intelligence of man, and would be found to grow out of and conform to his nature." Vitoria was motivated by stories circulating at that time about the shameful treatment of the natives of North and South America by invading Europeans—a situation not unlike that which could arise when space-travel extends its scope.

Needless to say, it is "natural law" that Haley has in mind when he envisages a world-wide Authority to control space-travel, and to co-operate with "other planetary authorities" to "contain violence," etc. It will, of course, apply strictly the "Great Rule of Metalaw."

Methods for the Study of the Juridical Problems which will Arise from the Conquest of Interplanetary Space.—Aldo Armando Cocca, of Argentina, wrote this paper when a student working under Dr. A. Ambrosini, who read it for him at the Congress, when a running English translation was provided. The paper is printed in Spanish with a French abstract.

Space-flight, the author says, will bring a new conception of law, and its most fundamental concepts, hitherto considered unalterable, will have to be revised. In particular, he points out that Einstein conceived a four-dimensional space-time continuum, and Cocca evidently takes into account the interchangeability of space and time when the same event is observed by different observers, for he enunciates the following principles which are said to follow the application of Einstein's theory to questions of law:

(1) Time is a determining factor in law, both in a precise mathematical sense and in a historical sense.

(2) In consequence, law is mutable and variable, just as is time.

Astronautics, he adds, provides a positive instrument for juridical speculation, namely, the overriding strength of the time factor. But he gives no examples of how these philosophical ideas can be applied in practice.

Studies and Research on the Juridical Problems Set by Astronautics.—Eugéne Pèpin, Director of the Institute of International Law in Montreal, circulated a short paper mentioning recent meetings at which questions of space law were raised. These were:—

(1) April, 1956, American Society of International Law.

(2) July, 1956, General Assembly of the International Civil Aviation Organization.

(3) September 1, 1956, International Law Association, meeting at Dubrovnik, Yugoslavia.

(4) At the Institute of International Aerial Law at McGill University, Montreal.

A Camouflaged Space Station.—Fredrico Romano, of Rome, looked into the future and saw astronautical experts being asked to co-operate with the military authorities in setting up a space-station which could be camouflaged to avoid destruction by a terrestrial enemy—for, he continued, history showed that

anyone with valuable possessions had to defend them against attack, and, he added, you cannot ignore reality.

Having thus set the tone, he proceeded to work out methods of defending a manned satellite space-station from destruction by tele-guided missiles. He thought it could be done, firstly, by eliminating radar echos and any sources of light, visible or invisible; plastic materials would be used, and the surface of the station made opaque to light. But he admitted he had not solved the problem of suppressing infra-red rays. Alternatively, hostile missiles would have to be attacked with anti-missiles of higher efficiency.

At the reading of this paper to the delegates, no clue was given as to the use to be made of the station when its crew were not preoccupied in warding off attacks.

Space Medicine

Undoubtedly the paper of most obvious interest in this section is that by Dr. Gerathewohl, who describes the most comprehensive experiments on weightlessness yet carried out. During the Congress he told the writer that durations of 45 or 47 seconds should be possible with the aircraft used, but the longest duration he reports is 30 seconds, and not all the flights produced complete weightlessness throughout. It seems a difficult matter to pilot an aeroplane at the exact speed and along the exact path which would be followed by a projectile in a vacuum, and perhaps an "automatic pilot" needs to be devised for the purpose.

Major Simons's paper on cosmic radiation showed how many people are patiently plodding along towards an answer to this problem, undeterred by its elusiveness. And Dr. Strughold's concluding remarks hardly increase the chances of fulfilment of every would-be astronaut's dream of finding a perfect planetary civilization established somewhere in the Universe.

The Ecosphere in the Solar Planetary System.—Dr. Herbertus Strughold, Head of the Department of Space Medicine, United States Air Force, proposes three subdivisions of his original conception of the "ecosphere," meaning a spherical region round the Sun which is neither too near to it or too far from it for life to exist (ecology being the study of the relations between living things and their environment). Strughold shows that this spherical region must be of limited thickness not only because of the direct effect of temperature on life, but because of two other effects which also depend upon the temperature being within the same limited range. So he proposes the adoption of three new names; and, as the orbits of the planets lie roughly in the same plane, he proposes that such a region should be called a belt rather than a sphere.

First on the list is the "biotemperature belt," which is determined by the fact that life processes are only possible between about 50° C. down to some degrees below O° C. Strughold's conclusion that only Venus, Earth and Mars cover this range is illustrated by a diagram which depicts the whole temperature range on the cloud surface of Venus and the solid surfaces of the Earth and Mars, but the temperatures of only the sunlit side of Mercury and the visible cloud surfaces of Jupiter and Saturn.

Next comes the "liquid water belt," a term already suggested by Harlow Shapley in a recent symposium on "Climatic Change." The same three planets come into this belt, for much the same reason as before, because water must be in the liquid form to be "biologically usable." (The author does not discuss the precise extent to which this fact determines the biotemperature belt.)

Finally, there is an "oxygen belt," and Strughold's discussion of it is the most novel feature of his paper. The presence of oxygen in a planet's atmosphere is likewise dependent on its distance from the Sun, for too much heat causes any oxygen molecules present to escape into space, while beyond a certain distance there is too little radiation to split any water molecules at the top of the atmosphere into oxygen and hydrogen. But if the planet is near enough to the Sun for this splitting to take place, the hydrogen flies away and the oxygen remains and oxidizes the primitive atmosphere; after which, more oxygen can be added by plants.

Although the most primitive forms of life can carry on without oxygen, higher organisms like man use energy at such a rate that it can only be provided by the oxidation of ingested food, so an oxygen atmosphere is a necessity for them.

Unfortunately the erstwhile simplicity of this idea of an "oxygen belt," in which the more advanced organisms can exist, is somewhat upset by complications such as the absence of detectable free oxygen on Mars, probably because it was too small to retain any, and on Venus for no very obvious reason at all, though Strughold suggests that it lost its oxygen through being too hot from solar radiation. These considerations make this third "belt" a lot thinner than the other two, until Strughold restores the balance by including carbon dioxide—which acquired its oxygen after the primeval splitting of water molecules—in the "oxygen belt," thus increasing its thickness to match that of the biotemperature and liquid water belts.

Strughold concludes by pointing out that his ecosphere, which includes these three belts, extends from about 50 to 150 million miles from the Sun; that is, it is only 100 million miles thick, which is less than 5 per cent. of the total radius of the solar system from the Sun to Pluto. And he quotes a recent estimate by Shapley which, if correct, would lead to the conclusion that there are only about 100,000 ecospheres in the whole Universe.

Personal Experiences during Short Periods of Weightlessness Reported by Sixteen Subjects.—Dr. S. J. Gerathewohl, of the School of Aviation Medicine in the United States Air Force, has been producing weightless periods of up to 30 seconds in the occupants of a Lockheed T-33A jet aircraft by getting the pilot to fly it on a parabolic path in a vertical plane. Actually, to produce complete weightlessness, it would be necessary to use just sufficient engine power throughout to counteract the effect of air resistance, which of course varies with the speed; only thus could the aircraft be made to follow the same path, in space and time, that it would in a vacuum.

It is evident, however, that much of the flying was done in sub-gravity rather than zero-gravity conditions, for Gerathewohl writes that the ascending arc of the parabola was flown at full throttle (not at continually diminishing

throttle), and the descending arc "with about 75 per cent. r.p.m.," sometimes on a parabolic path and sometimes in a 40-degree dive. The usual procedure was to fly a "subject" first on a descending arc only, four times in succession; with the hood closed, they kept their eyes open on the first trial, closed on the second, observed a floating object on the third, and then threw the hood back on the fourth so as to be able to see out. Each of these dives started from about 20,000 feet. After this the whole parabola, up and down, was flown three times, taking 30 seconds each time. The list of instructions to the "subject" concluded with the words: "Remember: in a few years, people will have to live and work in sub- and zero-gravity for some hours or even days. Your contribution is essential for the exploration of space."

Rather unexpectedly, eight of the sixteen subjects found the weightless sensation pleasant, three were indifferent to it, and only five had unpleasant symptoms. They were asked to record their feelings, and most of them did so. It is noteworthy that two definitely recorded that they had no sensation of falling, two had it for the first few seconds only, two felt they had somersaulted backwards and one that he was doing so forwards. On some flights they did aiming tests and usually aimed high. Some undid their belts and allowed themselves to float.

At the Congress Dr. Gerathewohl showed a film taken during some of the weightless periods. When a bottle of water was made to float in the cockpit, the water refused to come out unless shaken, and then the drops would hover around the bottle mouth, slowly drifting off in various directions.

In his discussion of these results, Gerathewohl referred to a paper given by the present writer to the third I.A.F. Congress and published in the B.I.S. *Annual Report* for 1952. In this paper it was suggested that the otolith organs of the inner ear, which normally register the direction of gravitational pull, either register nothing during weightlessness or else send nerve impulses at a rate characteristic of the condition. Gerathewohl suggests that the former is the case in those who have no sensations of motion, and the latter in those who do get such sensations at the onset of weightlessness.

He concludes that space crews will have to be selected according to their reactions to such preliminary experiments, but admits the results may not apply to prolonged periods of hours or days of weightlessness. And he quotes D. G. Simons as pointing out that sea-sickness does not show itself until some 15 or 20 minutes' experience of a rough sea.

Motor Co-ordination Behaviour in Subjects Exposed to Acceleration Values of Three to Zero "g."—T. Lomonaco, M. Strollo and L. Fabris, of the Study and Research Centre for Aviation Medicine in Rome, had built a sort of skeleton tower of metal framework, 46 ft. high, inside which the subject of the experiment was repeatedly jerked up and down while sitting in a mocked-up cockpit. Each "run" consists of three consecutive bounces up and down during 8 seconds. Strong elastic cords retard the the cockpit as it nears the bottom and pull it up again with a maximum acceleration of 3 *g*, whereas the upper part of the trajectory, up and then down, is traversed in the weightless state, which lasts for 1·70, 1·30 and 1·00 seconds respectively during the three successive bounces.

Thirty "healthy male subjects," aged 20 to 24, were given spells in this device, and were instructed to make jabs at a target, drawn on paper, during the weightless periods. The trials showed a tendency for more hits to be made in the upper right quadrant of the target than in any other quadrant, evidently because the muscles involved were accustomed to compensating for the weight of the arm, and over-compensated when the weight was absent.

Biological Effects of Primary Cosmic Radiation.—Major D. G. Simons, of the Space Biology Branch of the Aero Medical Field Laboratory in New Mexico, described how animals, plants and portions of living tissue were taken up by plastic balloons to heights of over 30 km. (nearly 100,000 ft.) to test the effects of exposure to cosmic radiation for periods of up to 30 hours. The balloons had diameters of between 85 and 172 ft. and were filled with helium; the biological specimens were enclosed in a sealed capsule with a weight of 160 lb., later reduced to 90 lb. by re-designing. The first capsules were of aluminium, but later fibre-glass was used.

The atmosphere in the capsule was replenished from a cylinder of compressed oxygen carried outside, and carbon dioxide was removed with soda-lime. Temperature tended to rise during the day because of the body heat of the animals, and had then to be lowered by circulating the air round a water-can cooler by means of a thermostatically controlled fan; there was also an insulating layer of 2½ in. of Lockfoam round the capsule. Readings of temperature and pressure in the capsule, and of the height of the balloon, were transmitted to Earth, and the balloon was tracked by radar.

Two kinds of evidence were looked for: generalized effects on animals, and localized effects on tissue cells. The first kind included examination of the behaviour and learning ability of two monkeys which were sent up several times and spent a total of 63 hours above 30 km. They ought, by calculation, to have received about 8,600 hits by the heavier types of cosmic nuclei during this period, but no harm to their mental or bodily health could be detected.

Nerve cells, including those which make up the brain, are irreplaceable, unlike the cells of most other tissues; hence their importance in these studies. But the brain of a cat, exposed for 16 hours above 30 km., showed no evidence under the microscope of damage by cosmic particles, nor did many other specimens of nerve tissue.

The replacement of some of the hairs of black mice by grey hairs, due to cosmic radiation, has already been in the news; the cells supplying the black pigment at the hair root are "highly radiosensitive" and are irreplaceable. An important finding in these experiments is an occasional streak of discoloured hairs several millimetres long and showing damage as much as 200 microns wide, which, Simons points out, is evidence of a radial spread of the damage ten times larger than expected. A piece of exposed mouse skin reimplanted afterwards in the mouse by Dr. J. Eugster, of Switzerland, showed a developing tumour of the type called granuloma at the site of one cosmic particle hit; this finding hints at a possible risk of cancer being started up by cosmic radiation exposure.

Young organisms in an early stage of growth were exposed. Radish seeds

showed no effect, but some interference with the growth of onion and snapdragon seeds and of grasshopper eggs was suspected. Chicken eggs, it was found, "were not well suited to balloon experiments because of their marked sensitivity to accelerative forces," to quote the scientific language of the paper.

As to the risk of deformities due to mutations in the offspring of space crews, Simons writes truly: "The genetic effects characteristic of cosmic-ray particles will be of intense interest to all but senile crew members." But although vegetable seeds showed some effect, the only animals exposed, 969 fruit-flies, which showed no effects, were considered to be a "statistically inadequate sample"!

A particularly interesting observation by H. Yagoda is brought to light in this paper. He has found that the intensity of low-energy cosmic-ray primary particles has increased during the past few years, and "a large flux of particles with energy slightly below the minimum energy previously observed." (Though Simons does not mention it, a suggestion has been made that the absence in the Earth's neighbourhood of particles with energy below a certain minimum is due to their being kept away by the magnetic field of the Sun, in which case changes in its strength might be responsible for the fluctuations found by Yagoda.) Simons remarks that, if there really has been such a change, "the hit probability calculations based on earlier data may be too low by a factor of two or more."

One cannot help wondering if space travellers of the future will, because of this phenomenon, wait for a clearance of the cosmic weather, so to speak, before setting out among the hazards of cosmic radiation.

TECHNICAL REVIEW

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Problems of Communication in Interplanetary Flight

In *Aviation Week* for September 3, 1956, P. A. Castruccio, of Westinghouse Electric, Baltimore, presents a paper which describes some of the problems of the design of communication and collision radar systems for vehicles in interplanetary flight. He points out that, for navigational purposes, the angular errors in the vehicle trajectories must be very small: for the Earth-Mars trip, with a vehicle speed of 12 miles/sec., an error of 1 min. of arc would result in an error of position at the end of the trip of 30,000 miles, while a 1 per cent. error in initial velocity would cause an error of 500,000 miles. Although small compared with the distance travelled, these errors would require the combustion of extra propellents to place the vehicle in the correct orbit.

As propulsion systems improve, the capability for manoeuvre will do so likewise, and so we may envisage two phases of travel: (1) with chemically-propelled vehicles, using carefully timed trajectories, and (2) the slow increase of regular and perhaps dense interplanetary traffic. In the first case, navigation will be almost exclusively optical, with, perhaps, Earth-based navigational computors linked to the vehicle by radio, and collision radar for meteors, while the second case will call for the development of automatic navigational aids. Measurement

of absolute position cannot be made by reference to the stars, due to their great distance, and all that can be got is the direction of the radius vector from the co-ordinate system origin to the vehicle: the magnitude of the radius vector can be calculated from the apparent radius of the Sun, with an error, for one second of arc error in measurement of the Sun's apparent angular diameter, of 100,000 miles at the distance of the Earth from the Sun (100,000,000 miles). Use of the planets to determine position is more accurate than the above, but it requires the vehicle to carry an accurate clock: for navigation within the orbit of Mars, with instruments accurate to 1 sec. of arc and 1/100 sec. of time, the positional error is about 1,000 miles.

The use of radar techniques will be basically similar to their use on Earth, except that the radar system will move with respect to the solar system's reference frame, which complicates matters by the movement of both the beam and the vehicle relative to the point of arrival. However, it is possible to consider the following schemes:—beams aimed between planets, which would form polygons with sides equal to the shortest distances between planets: swept beams which periodically cover large regions of space; and broad or omni-directional beam systems which provide an intercept course. The first system is a so-called "beam rider," but it makes for a long flight path and very high terminal accelerations, which counteract the convenient features of the guidance. The third method (and perhaps the second) permits the vehicle to home on to its destination, and, by proportional navigation, follow automatically the shortest straight line collision course. The source of the beam could be situated on the destination planet or a satellite, and rotated to compensate for its base's movement.

Considering power, accuracy and range requirements, Dr. Castruccio states that, in the 3 cm. X band, an aerial of 30 ft. diameter could provide guidance from Earth to Mars at its closest distance with an accuracy of 10,000 miles which is possibly unnecessarily high. With predictable techniques, a transmitting system with a beam 24° wide (to 3 db down), with a power of 10 kW average will have a reliable range of about 140 million miles, assuming a receiver with a 10 sq. ft. aerial and a 1 db signal/noise ratio. By increasing the frequency it would be ultimately possible, with 24° beams, to work out to $2{\cdot}1 \times 10^9$ miles, sufficient for traffic within the orbit of Uranus. The beam will also yield a direct measurement of the vehicle's velocity relative to the transmitter, by the Doppler effect. Another system, akin to the Loran hyperbolic pulse system now in use, which would use four beacon transmitters on different planets, would permit absolute determination of position by observing the time intervals between marker pulses as received at the vehicle. Such a system would have to use omnidirectional transmitters, and, with the same receiver as above, and 10 kW average power at the transmitter, the reliable range would be only 10 million miles, which is too short for any interplanetary work. Improvements should be possible, however, by cooling the receivers and so reducing the noise voltages, and by extending the time during which the signals are observed. If the receiver is cooled, a three-fold increase in range would be gained, and an observation time of 1 min. would extend this to 300 million miles, or out to the Asteroids. A further improvement of ten on the performance of the receiver

would give another three-fold increase in range to 10^9 miles, satisfactory within the orbit of Saturn.

If we restrict operations to a region not far from the ecliptic, to, say, a 10° sector, "a range of about 4×10^9 miles could be achieved with 1970 techniques and with a 10-minute signal observation time." Such a system, with Doppler velocity measurement, would give an automatic determination of position and velocity, continuously.

For communication, base-to-vehicle working is facilitated by the use of a very large transmitter: using single sideband voice transmission, an omni-directional transmitter of 100 kW average power would give a range of 6·2 million miles with a 10 sq. ft. receiving aerial. Range varies as the square root of the power, so that even a 2 megawatt transmitter would get only to 28 million miles. However, by using beamed transmission, and using a 24° beam and 100 kW power we could get to 62 million miles. This, of course, means that the beam must be pointed to where the vehicle is. Cooling the receiver may give up to three times the range, but we cannot rely on extended observation times for voice communication: the use of telegraphy (teleprint) with long times for observation could give, by spreading one minute's message over an hour, an eight-fold increase in range, and if a large aerial could be erected (say 100 sq. metres), we could, with 100 kW transmitted power, get out to 600 million miles. Making the further assumption that the vehicle lay in a particular octant, this, by using a directional beam, would give a total range of $1{\cdot}6 \times 10^9$ miles.

For vehicle to base, things are different. Transmitted powers will never be so high, but it will always be known where the base is, so that narrow beams can be used. With a 1 kW transmitter, using a 2° beam, a range of about $2{\cdot}2 \times 10^9$ miles should be attainable with a 10 sq. ft. receiving aerial at the base.

Vehicle-to-vehicle communication may be accomplished by the use of suitably located transponder beacons, but as soon as traffic increased there would be troubles with overloading the beacons. Considering only relatively short-range communication between vehicles, it appears that, by working in the 200 megacycle band with a power of 1 kW, a 10 sq. ft. aerial and a cooled receiver, a range of 1·8 million miles could be achieved for voice transmission. By using narrow beams, the range can be increased, at the expense of scanning the region to find the other vehicle: this involves delays due to the finite speed of radiation. It would be necessary to send a message on a given bearing and wait for a response (8 min. for 50 million miles) before going on to another position, although it might be possible to record the successive positions of the transmitting aerial, to listen out continuously for a response, and then redirect the transmitter to its previous bearing.

The possible use of collision radar for detecting meteorites seems rather difficult, due to their small size (and small reflected image) and great speed. Let us consider that a meteorite has a cross-sectional area of 0·1 sq. ft., and that this is taken as the smallest against which protection is needed (this will weigh about 1 lb.) while the radar aerial has an area of 10 sq. ft., with a wavelength of 4 mm. and peak power of 100 kW (as may be achieved in, say, 20 years). The minimum band width of the radar set is limited by the Doppler shift due to high speeds of approach of the meteorites, and it appears that a width of at

least 30 megacycles is needed: also, in any radar system there will be an inefficiency due to losses, and this may be assumed to be 6 db (4/1): the signal to noise ratio needs also to be about 6 db for reliable automatic warning. From this, the author indicates that the range of the set is only 25 miles: even with improvements (including better intermediate frequency circuits and cooling) a range of 100 miles about the limit. This gives, for a relative speed of 40 miles/sec. between meteorite and vehicle, a total time of only $2\frac{1}{2}$ sec. for detection, tracking, determination of the course being a collision one, and taking the correct (computed) evasive action. The author concludes in this respect that radar is little use except for rearward meteorite attack.

The paper concludes by discussing the use of radio methods for planetary mapping and investigation. Optical methods should be used where possible, but on cloudy planets, such as Venus, radar would be useful. Radar would be a help in determining atmospheric constituents, by selective absorption; water vapour exhibits strong absorption at 1·25 cm., and oxygen at 5 mm.

Rotational Period of the Planet Venus

In a letter to the editors in *Nature*, September 29, 1956, J. D. Kraus, of Ohio State University, reports some measurements he has made of the apparent period of rotation of Venus, by analysing the radio activity heard on a wavelength of 11 metres. He states that, by noting the intervals between peak intensities of activity, there is a time of 12·75 or 13 days, which represents the interval between corresponding points on the Earth and Venus coming together in the same angular relationship, and from this it is deduced that a probable value for the rotational period is 22 hr. 17 min. $\pm$ 10 min. It is stated that the most probable mechanism for the production of the peaks is as follows:—If Venus has an intense ionosphere, the radio activity can only emerge through it in the region of a "hole" which will be overhead a particular source: this activity will only be received from, or near, the centre of the planet's disc. If the source of activity rotates with the planet (if it be a thunderstorm low down, for example), the activity will be observed only at intervals which are equal to, or multiples of, the planet's rotational period.

Aerobee-Hi Firings

After five abortive attempts, the sixth Aerobee-Hi has established a record "for an American-built boosted rocket," it is stated in *Jet Propulsion* for August, 1956. This happened at White Sands on June 29, 1956. Aerobee-Hi has had trouble in its development, and the report lists the snags:—

(1) August, 1955. Complete failure owing to a "too-safe" gas pressure regulator, which did not permit the main motor to fire.

(2) December, 1955. Complete failure due to a hard start, which completely wrecked the vehicle.

(3) May, 1956. Complete failure due to fault in range safety circuits.

(4) Partial failure—rose to 117 miles only as a result of premature failure of the combustion chamber.

(5) Another partial failure as (4), at 40 miles.

During the sixth firing the Aerobee-Hi exceeded the Viking record of 158 miles in May, 1954, and got to a speed of 4,435 m.p.h. The rocket was very stable, and did not tumble after the end of burning.

Research and Development Facilities

Aviation Week, October 1, 1956, states that the Westinghouse Research Laboratories in Pittsburgh have seven acres of floor space, on which are 450 scientists and their helpers, and one million dollars' worth of equipment. Topics of interest are inconel cladding of molybdenum, to prevent oxidation at high temperatures; design of nickel alloys; light-beam amplifiers; and the effects of very low temperatures on electrical memory systems, where superconductivity permits a current to circulate continually, without loss.

There are two tunnel facilities reported: one (*Aviation Week*, September 24, 1956) at the U.S.A.F. Arnold Engineering Development Centre uses the discharge from a large bank of capacitors across an air chamber to burst a diaphragm and send a relatively long-duration hypersonic stream past a stationary model. The tunnel is called "Hot Shot": it produces a speed of 11,000 m.p.h. ($M = 15$) for 10 milliseconds, with a stagnation temperature of about 8,000° K. The current is about one million amperes. The other tunnel is at the Armour Research Foundation (*Jet Propulsion*, August, 1956): this is also a shock tube, and is being used at the moment for simulating meteorite bombardment of metal surfaces. Common house dust at 4,000 ft./sec. will penetrate a copper sheet 0·008 in. thick.

High-speed Rocket Vehicles

Aviation Week, October 8, 1956, reports that two new portable and inexpensive rockets for upper atmosphere research have been developed. The first is Terrapin, due to the University of Maryland and Republic Aircraft, which is a two-stage solid propellant rocket, 15 ft. long × 6½ in. diameter, and which weights 224 lb. The first flight resulted in a height of 80 miles and a Mach number of 5·8 when fired by the N.A.C.A. at Wallops Island. The first stage took the rocket to 10,000 ft. in 6 sec. at 1,900 m.p.h.: it then coasted to 30,000 ft. before the second stage pushed it up to 50,000 ft. at 3,800 m.p.h. The temperature measured on the skin was about 800° K., and the instrumentation dealt with cosmic radiation, as well as vehicle behaviour. A design is being prepared for a three-stage vehicle to go 200 miles up.

The other rocket is Nike-Cajun, developed by the N.A.C.A. This also has two solid propellant motors, and will take a 40-lb. nose to 100 miles, at $M=6$. Over 100 Nike-Cajuns will be fired during the I.G.Y., and a device for photographing hurricanes is being developed for the U.S. Weather Bureau.

The U.S. Air Research and Development command at Holloman Air Force Base are using a two-stage solid-propellant rocket called HTV (Hypersonic Test Vehicle), according to *Aviation Week*, September 17, 1950. This uses seven small rockets in the boost stage, and four in the main rocket, each set of rockets being ignited simultaneously. Each stage is 5 ft. long, and the main rocket is

6 in. diameter while the boost is 9 in. diameter; there is a 2-ft. long nose-cone. No performance is stated.

Bibliographies

Two useful bibliographies are now published in *Jet Propulsion*. The first (August, 1956) is entitled "Ten Years of Project SQUID": SQUID was started in 1946 as a joint effort between the U.S. Navy Bureau of Aeronautics and five university laboratories, as a device to use academic brains on some of the problems of pulse-jet and liquid-rocket engines. This has expanded to cover, in a fairly general way (with jet propulsion as its main object) combustion, fluid flow, and heat transfer, and now the project is sponsored by the Office of Naval Research; also the number of participating groups has extended to nineteen.

The bibliography covers 20 pages, and is subdivided into six sections: Properties of Materials (Transport and Structural), Physical Processes (Heat and Mass Transfer, Fluid Flow), Chemical Processes, Combustion Phenomena, Engines and Propulsion Systems, and Instrumentation. A fairly extensive summary of each paper is given, and the whole is a valuable reference source.

The other bibliography ("Jets—Review of Literature") appears in the September, 1956, *Jet Propulsion*, and has been compiled by M. Z. v. Krzywoblocki, of the University of Illinois and the U.S. Naval Ordnance Test Station, Inyokern. It deals "with the fundamentals and mathematical theory of free boundary flow and jets; with the distribution of velocity, density, pressure and temperature in laminar jets; transport of mass, momentum and energy in turbulent jets; and with closely related phenomena—the acoustical ones, designing of nozzles, orifices, wind tunnels with open jets, etc., being excluded. The review is divided into eight sections." These are:—

(1) Fundamental and Mathematical Theory of Free Boundary Flow and Jets;

(2) Distribution of Velocity, Density, Pressure and Temperature in Supersonic and Submerged Jets;

(3) Transport of Mass, Momentum and Energy; Diffusion in Turbulent Jets; Entrainment of Air; Injectors;

(4) Jet Mixing of Two Fluids; Parallel and Multiple Jets;

(5) Jet and Perpendicular Stream, Impinging Jets on Obstacles, Interaction between Jets and Surfaces;

(6) Sonic, Cavitation, and Capillary Phenomena; Waves in Jets; Pulsations, Perturbations, Stability;

(7) Ejectors, Thrust Augmentors, and Flow Coefficients; and

(8) Effect of Jet on Airplane Stability, Application of Jet Theory to Practical Purposes.

The bibliography covers 18 pages, and includes reports dated 1956 as well as such classical contributions as the works of Boussinesq, Chaplygin, and Rayleigh. A world-wide coverage is given. The bibliography complements the list of SQUID reports, and is a very useful survey of the literature.

Current Work at N.A.C.A.

As a result of the 1956 Triennial Inspection of the N.A.C.A. Langley Aeronautical Laboratory, *Aviation Week* (October 15, 22, and 29, 1956) has devoted considerable space to work in hand there. Matters of specific interest to the satellite ballistic missile worker include, primarily, aerodynamic heating, and also matters of control at hypersonic speeds. Aerodynamic heating is being studied in the laboratory, by blowing hot gas jets at models: sources for this gas are:—a ceramic heat exchanger, externally heated, through which air can be blown to give a velocity of 5,000 ft./sec. at about 2,200° C.; a rocket jet tunnel (using nitric acid and ammonia) giving 7,000 ft./sec. and 2,200° C., with exhaust products of oxygen, nitrogen, and water vapour; and an air/ethylene combustion chamber giving 4,300 ft./sec. at 1,900° C. These facilities vary in size, the ceramic heat exchanger unit providing a jet of $\frac{3}{4}$ in. diameter (a larger unit is being built), the rocket unit giving a jet of $2\frac{1}{2}$ in. diameter, and the ethylene unit giving a 12-in. diameter jet.

Free flight testing is done with a number of vehicles: they are all driven by solid propellant motors, in three or four stages. The latest is a four-stage vehicle, comprising (1) an Honest John motor, (2) a Nike boost, (3) a Thiokol T-40 motor, and (4) the vehicle proper, which is aided by a Thiokol T-55 motor, and is about 6 in. diameter and 6 ft. long, with an ogival blunt-tip nose and a flared skirt instead of fins. Another, a materials test vehicle, is fitted with a number of probes mounted on the cylindrical body section: these project outside the boundary layer and consist of forward-facing hemispheres of different materials, fitted with thermocouples. In order to study heat transfer to a vehicle at incidence to the relative wind, a test vehicle has been designed which has two models placed side by side at its nose; these models are given symmetrical pitch angles, so that there is no resultant force on the vehicle as a whole, and the incidence of the models will remain known. This will be boosted by an Honest John motor, and should get to $M = 5$; the other vehicles get to $M = 10$, and the first one, in 1954, to do this, consisted of two Nike boosts and two Thiokol motors, all stock items; it was nearly 36 ft. long and got to $M = 10{\cdot}4$ at 84,000 ft. before coasting to about 1,000,000 ft. All these firings are done at Wallops Island.

The N.A.C.A. use both laboratory testing and free-flight work to solve any given problem: an example quoted is that of a vehicle (Honest John/Nike booster) designed for getting data on the aerodynamic heating of a nose cone. This should have achieved $M = 5$, but 2 sec. after ignition of the second stage the vehicle yawed violently and crashed, indicating the failure of a stabilizing fin, made of magnesium alloy. Tests on specimen fins in the air/ethylene jet facility indicated that the prototype fin, with a sharp leading edge, was getting burnt away to a considerable extent in the running time of 2·3 sec. at 1,000° C. A second model, in which the leading edge was rounded off, showed better performance, but it was not until an inconel-clad leading edge was used that a completely satisfactory fin was obtained, which was then used in flight tests.

Shock Tube Instrumentation

The Cornell Aeronautical Laboratory has had considerable experience with

shock tubes, and a note (*A.W.*, October 29, 1956) is available which describes some of the instrumentation used there. The major problem is that of getting good response time: since the shock tube produces transient phenomena which last only a few milliseconds, both instruments and recorders must be fast-acting. Pressures are being measured by quartz-crystal piezo-electric gauges, and the forces on models are recorded by the use of accelerometers rather than by quasi-static instruments such as are used in wind tunnels, while the flow visualization systems use schlieren techniques with high-speed motion-picture cameras and spark sources. However, the most interesting development is that of a fast-acting thermometer, which consists of a platinum film baked on to a glass base: the metal thickness is 4×10^{-6} in., the time constant is 6×10^{-8} sec., and the nominal sensitivity is 6 mV./° C. (the applied voltage is not stated). The instrument is made by painting commercial printed circuit paint on to either fused quartz or Pyrex glass and firing it at about 700° C., which softens the base slightly and allows the oxide flux in the paint to unite with the glass, and calibration is performed by mounting the thermometers at the stagnation points of spherical models in a shock tube.

Heat Transfer in Shock Tubes

Robert Bromberg, of the Ramo-Wooldridge Corporation, discusses in the September, 1956 *Jet Propulsion* the "Use of the Shock Tube Wall Boundary Layer in Heat Transfer Studies," in a largely mathematical paper. Such a boundary layer differs from the normal one, in that it has a relatively low free-stream velocity and a high (non-zero) velocity at the plane wall, but the shear stress and heat transfer vary with distance from a leading edge in the same manner as in the stationary case. This permits, since the shock-wave layer is amenable to analytical and experimental investigation, the examination of boundary layers under severe conditions of heat transfer and shear stress.

Low Temperature Storage of Radicals

The *Engineers' Digest*, November, 1956, has a note about the storage of highly reactive molecular fragments by freezing them with liquid helium. Such a process has obvious interest with regard to the analysis of the products of combustion of rocket propellants. In the experiments considered, the radicals are produced in a high frequency (2,450 Mc/s) discharge by the passage of gases containing nitrogen, hydrogen, oxygen, or water, and are then frozen at 4·2° K. This is accomplished by leading them to a metal surface in contact with liquid helium, care being taken that the drop in temperature is as sudden as possible, so that the unstable fragments solidify and do not recombine: solids have been obtained which contain atomic nitrogen and oxygen, and, perhaps, atomic hydrogen and a hydroxy radical. These solids are very remarkable: they emit a bright glow, blue "flames," and coloured flashes of light. When warmed 20 or 30 degrees, they combined actively, releasing stored energy principally as heat.

Impact Phenomena at High Speeds

In the *Journal of Applied Physics*, October, 1956, Von Valkenburg and Clay, of the University of Utah describe experiments they have made on the impact

of small (3 mm.) spherical particles on to metal surfaces. While the maximum achievable velocity (about 5,000 m./sec.) is much less than those associated with meteoric impact on a satellite or extraterrestrial vehicle (up to about 80,000 m./sec.) this work serves as an introduction to the problem. Some attention to this matter has been given already in Technical Review, with regard to the method of accelerating the particles; the conclusion of the present paper is that the volume of the crater per unit energy of the impacting pellet is essentially constant for each material, and that the penetration is proportional to the velocity of the pellet so long as the pellet velocity is less than the velocity of sound in the target material (which is not necessarily the case for meteorite impact). The "supersonic" case has been studied to a restricted extent by using soft wax targets with a low acoustic velocity.

Radio Echoes and the Electron Content of the Atmosphere

Browne, Evans, Hargreaves and Murray, of the Jodrell Bank Experimental Station, University of Manchester, have written a paper (*Proc. Phys. Soc.*, September 13, 1956) in which they describe experiments on the reflection of pulses at 120 Mc/s, horizontally polarized. They discuss the theory of echoes from the Moon, and consider the manner in which the lunar surface scatters the incident radiation, as well as the rotation of the plane of polarization by the ionosphere. Results are that the Moon reflects radio waves as if it were uniformly "bright," with a power reflection coefficient of less than 0·1. The rotation of the polarization plane, which appears as long-period fading of the signal, is used to determine the total electron content in the atmosphere, and the agreement of the data obtained with conventional F-layer data is discussed.

This work is elaborated by a further discussion of the results in a paper, in the same issue, by Evans.

"Vanguard" Satellite Notes

Some news is available: after the first flush of information the satellite project in the U.S.A. has taken up less space recently, but no doubt there will be plenty when launching time approaches. In *Aviation Week*, October 15, 1956, the manufacturing manager of the Glenn L. Martin Co. for Vanguard said that one success out of a dozen firings would be a good average, and in another note (*A.W.*, November 5, 1956) there is a description of some of the manufacturing techniques and gauges used to ensure accurate alignment of the vehicle assembly: it is mentioned there that the overall structural weight will be 14 per cent. of the gross weight, which is to be about 22,000 lb. The launching stand has also been described (*A.W.*, November 26, 1956); it is also capable of acting as a static test stand for the 27,000 lb. thrust first-stage motor. It consists of a steel structure about 15 ft. square and 11 or 12 ft. tall, with a water-cooled elbow to deflect the exhaust at 90 degrees.

"Nike" Engine Details

Details of the rocket engine used in the surface-to-air guided weapon Nike are available (*A.W.*, October 22, 1956). The original engine for Nike was

developed by Aerojet, but the present note describes the alternative engine made by Bell Aircraft to a new specification. The Bell engine gives a specific impulse of 212 sec. for 35 sec., the thrust being 2,600 lb. at 10,000 ft.: the propellants are kerosene and R.F.N.A., and the chamber pressure is 330 lb./in.^{2} The chamber, 6½ in. diameter and 18½ in. long, weighs 20 lb. and is uncooled, the lining being made of Carborundum Niafrax "A" ceramic. The main troubles during the development were apparently due to nozzle erosion (the area increased by up to 100 per cent. during firing!) which was overcome by relocating the oxidant jets, and combustion instability which could lead to physical destruction of the combustion chamber, which was rectified by another injector modification.

Miscellany

Dr. Hubertus Strughold (*Jet Propulsion*, September, 1956) reviews the "Medical Problems in Orbital Space Flight"; in the same issue there is a paper by L. Ivan Epstein of the Glenn L. Martin Co. on a mathematical method of designing solid propellant charges, while (*Jet Propulsion*, August, 1956) Leon Green of Aerojet-General describes "Observations on the Irregular Reaction of Solid Propellant Charges": this is a readable discussion of the subject after the mathematics of Cheng and others. Some Vanguard details are available: it is stated (*Aviation Week*, August 27, 1956) that the satellite itself will have a skin 0·030 in. thick, made of a magnesium alloy; the outer surface will be smoothed to a 4 micro-inch roughness, and then mirror-finished to aid observation (and presumably to minimize heat losses). The diameter is 20 in., and the weight 4 lb. The inertial guidance unit, mounted in the third stage, is made by Minneapolis-Honeywell, and uses three integrating gyros which work in the roll, pitch and yaw axes; signals operate magnetic amplifiers and servo motors which tilt the gimbal-mounted engines of the first and second stages to maintain required altitude and trajectory; the programmed tilt of the vehicle is introduced by a small torque motor which biases the pitch axis gyro. A transistor amplifier acts as a thermostat for the gyro damping fluid (*Aviation Week*, September 24, 1956). The third stage will be spun and separated by small solid propellant units made by Atlantic Research Corp. (*Aviation Week*, August 20, 1956). Auxiliary rockets on the third stage will rotate it and the attached satellite, while the second stage is still joined. After the full spin of 200 r.p.m. has been achieved, retro-rockets will be fired to retard the burnt-out second stage and separate the stages positively, after which the third stage fires. The U.S. Air Force has started a 90,000-mile flight to map the world's magnetic field more accurately (*Aviation Week*, September 24, 1956); the Stratofreighter aircraft will cover a 1,800 mile-wide band embracing the Equator, and will measure cosmic-ray intensities at a constant altitude of 18,000 ft. D. Napier & Son, Ltd., Luton, are reported (*Aviation Week*, September 24, 1956) to be developing a series of H.T.P./Kerosene rocket engines, for missile and aircraft use, with controllable thrust. Napiers have been working on rocket engines for the last six years.

OBSERVATIONS OF ARTIFICIAL SATELLITES—2

By J. Humphries, B.Sc.(Eng.), A.M.I.Mech.E., A.F.R.Ae.S.

Since the last issue of the Journal a great deal of progress has been reported from the American Moonwatch programme. At the time of writing (January 17) it is known that nearly 100 observation stations have been formed within the United States. So far no foreign stations have been reported although the announcement that the *Bulletin for Visual Observers of Satellites* is to be translated into Spanish indicates a growing interest in South America.

The prototype Moonwatch station was established at Silver Spring, Maryland, at the home of G. R. Wright, chairman of the national advisory committee. There, skilled amateur astronomers assisted in systematic tests of about 30 different optical instruments that had been proposed for visual tracking of artificial satellites. Both monoculars and binoculars were tested and it was decided that a monocular was almost as effective as a binocular having the same field, aperture and magnification. Wide-angle binoculars are generally unavailable and would be costly; therefore monoculars were favoured for Moonwatch teams. The design of a suitable instrument is described in the third issue of the *Bulletin*. This telescope provides a 12½ degree field with very good image brightness and has a magnification of 5·5 X. All optical parts are war-surplus items and the total cost (excluding labour) is less than $20. This, of course, applies to the United States and it remains to be seen if suitable optical equipment is available in Great Britain at a reasonable price.

Many of the American stations are now fully equipped and ready for operation. The members of most of the early teams provided their own equipment, but more recently formed teams have been obtaining sponsorship from various private business and public business organizations. Radio stations, newspapers, insurance companies, automobile agencies and municipal governments have agreed to defray the costs of setting up stations.

The first observing alert, originally scheduled for December 8, 1956, has been postponed to some time in early Spring, 1957. It will occur shortly after sunset and all registered teams across the United States are expected to hold serious observing practice sessions. The event is to be not only a dress rehearsal but there is also a real possibility that a nearby natural earth satellite may be discovered. A number of the observing stations (selected at random) may be able to see a simulated satellite. These will be aircraft flying at an altitude that will make their engines inaudible, with a course and speed approximately duplicating the apparent motion of an artificial satellite. Each 'plane is to carry a light that will match the expected brightness of the satellite as seen from the ground.

In the last Journal an appeal was made for helpers for the proposed B.I.S. Moonwatch programme. For the sake of new members this is repeated herewith. The qualifications for potential observers are an appreciable experience of astronomical observing and a willingess to turn up to a certain number of

practices and, of course, to turn out when suitable satellites have been launched. Would potential observers please write to J. Humphries, 97, Churchill Avenue, Southcourt, Aylesbury, Bucks., giving brief particulars of experience, including types of instruments used. Although it is almost certain that any activity will have to be confined to the London area, replies from all parts of the British Isles will be welcome in order to ascertain the degree of interest in the project.

In some of the satellites the Minitrack equipment may be left on throughout the complete orbit. Although the B.I.S. Moonwatch Committee has no further information at the moment on this proposal, it would also like to hear from members interested in helping in a Minitrack receiving station. The number of people involved would be small and only those professionally engaged in electronics or radio, or amateurs with very extensive experience, should apply. Please send details of qualifications and experience.

ABSTRACTS

Edited by J. Humphries

A list of abbreviations of titles of journals was included in the 1954 index.

ASTRONAUTICS

(1) **Artificial satellite, unification and mechanics (Sidar-mechanics).** A. Boni. *Astronautica Acta*, **1**, 120–136 (1955). Proposes the root "sidar" for the derivation of satellite terms, and discusses the unification of satellite-orbits, force-fields in satellite stations, and the requirements for the safety of inter-satellite traffic. (**14** *refs.*)

(2) **On the descent of winged orbital vehicles.** K. A. Ehricke. *Astronautica Acta*, **1**, 137–155 (1955). Conditions during the descent of an orbital glider are discussed and various means for the dissipation of the glider energy are evaluated. Base drag as well as drag due to lift is found to be an advantage. Wing loading and area must be kept small to permit the use of high incidences without the need for heat protection or cooling of large surfaces.

(3) **Optimal transfer between circular orbits about two planets.** D. F. Lawden. *Astronautica Acta*, **1**, 89–99 (1955). The general theory of optimal rocket trajectories is modified into a form convenient for the problem of transfer between circular orbits about two planets. The equations for the case of planets moving in coplanar elliptic orbits are derived. (**5** *refs.*)

(4) **In anticipation of interplanetary navigation.** G. A. Crocco. *Civiltà delle Macchine*, **3** (3), 49–53 (*May-June*, 1955). (*In Italian.*) Some considerations of the Earth satellite and the Earth-Mars voyage.

(5) **A physicist's views on interplanetary travel.** G. Thomson. *Discovery*, **16**, 425–9 (*Oct.*, 1955). A general survey of the problems extracted from the author's book *The Foreseeable Future*. He considers that space flight should be possible in the next 50–100 years.

(6) **On the possibility of space-flight by the aid of industry and present-day chemistry.** J. M. J. Kooy. *Ingenieur*, **68**, 0.41–0.54 (1956). (*In Dutch.*) Review of the use of unmanned artificial satellites and spaceships.

(7) **Perturbations of a satellite's orbit due to the Earth's oblateness.** L. Blitzer, M. Weisfeld and A. D. Wheelon. *J. Appl. Phys.*, **27**, 1141–9 (*Oct.*, 1956). For nearly circular orbits one finds that perturbations of the usual planar motion may be described analytically. These are characterized by a precession of the orbit plane around the equator, that is, a regression of the nodes, amounting to as much as 40 miles per revolution. By using conventional radio techniques these effects may be measured and the Earth's oblateness determined to a new precision. (**3** *refs.*)

(8) **One orbit out of twelve "good" satellite average, Martin says.** J. Dailey. *Aviation Wk.*, **65** (16), 30–1 (*Oct.* 15, 1956). Summary of lecture on Vanguard, giving orbital details. Radio amateurs will be able to build Minitrack receivers for about $1,000.

(9) **Vanguard depends on tools and gages.** D. A. Anderton. *Aviation Wk.*, **65** (19), 50, 52 (*Nov.* 5, 1956) Some details of the Vanguard structure, which will be 14 per cent. of the all-up weight. First step is largely light-alloy and second step largely stainless steel. Extensive static and dynamic tests will be carried out and the final assembly and tests will be done in a 90-ft. high fixture in a special building at Martin's.

(10) **Company formed to study space design.** I. Stone. *Aviation Wk.*, **65** (22), 51–2, 57–60 (*Nov.* 26, 1956). A new American company, Systems Laboratories Corp., has been formed for preliminary design of basic systems for interplanetary travel. The company is only six months old and has 44 employees. At present most of the firm's effort is being expended on various sub-contracts dealing with long-range missiles. Dr. Barnes, the President, considers that lunar instrument-carrying vehicles will be made within the next five to ten years. Effort is being put into theoretical studies of atomic rockets.

ASTRONOMY

(11) **Radio echoes from the Moon.** I. C. Browne, J. V. Evans, J. K. Hargreaves and W. A. S. Murray. *Proc. Phys. Soc. Sect. B.*, **69**, 901–20 (*Sept.* 1, 1956). Observations have been made from Sept. 1953 to Aug., 1955, using a pulsed transmitter operating at 120 mc/s. The first part of the paper discusses the theory of echoes from the Moon and the second part the results of the observations. The power reflection coefficient of the Moon's disc is found to be somewhat less than 0·1. The echoes are subject to rapid fading due to the Moon's libration. (16 *refs.*)

BIOLOGY AND MEDICINE

(12) **Protection of humans from heavy nuclei of cosmic radiation in regions outside the atmosphere.** H. J. Schaefer. *Astronautica Acta*, **1**, 100–9 (1955). Heavy nuclei of cosmic radiation cause severe local cellular damage particularly towards the ends of their tracks. Full shielding is impractical and ineffecive shielding may be worse than none. The Earth's magnetic field protects the equatorial regions from the these heavy primary particles. (7 *refs.*)

MISCELLANEOUS

(13) **Edwards' rocket base to test captive ballistic powerplants.** *Aviation Wk.*, 65 (6), 143, 145 (*Aug.* 6, 1956). Captive tests at up to 500,000 lb. thrust can be carried out at the Air Force Flight Test Centre. At present sixteen firings a week are carried out.

PHYSICS

(14) **On translational heat transfer in fast reactions.** H. J. Kaeppeler. *Astronautica Acta*, **1**, 111–9 (1955). (*In German.*) Conventional relations for calculation of heat transfer are not applicable to fast high-temperature reactions where thermodynamic equilibrium is not attained. The paper reports investigations leading to a modified translational heat-transfer coefficient, and discusses the possibility of reactions in nuclear jet power plants being quenched. (26 *refs.*)

(15) **Impact phenomenon at high speeds.** M. E. Van Valkenburg, W. G. Clay and J. H. Huth. *J Appl. Phys.*, **27**, 1123–9 (*Oct.*, 1956). A study of high-speed metal-to-metal impact in the velocity range 1 to 5 mm./μsec. using $\frac{1}{8}$ in. diam. spherical pellets. Pellet materials include aluminium, magnesium, steel, brass, lead and zinc. Experiments relating to the mechanisms of cratering and the perforation of thin targets are presented. It is found that the volume of the crater per unit energy of the impacting pellet is essentially constant for each material and that the penetration is proportional to the velocity of the pellet so long as the pellet velocity is less than the velocity of sound in the target material. An attempt to model very high speed impact by using soft wax targets in which the sonic velocity is less than the impacting velocity, is outlined. (12 *refs.*)

PROJECTILES

(16) **Patrick prepares for ballistic missiles.** D. A. Anderton. *Aviation Wk.*, **65** (6), 106–7, 109–11, 113, 115–6, 119, 121 (*Aug.* 6, 1956). Description of Air Force Missile Test Center and its facilities. During the next two years the base must triple its capacity and the range will be extended to 5,000 miles to deal with long-range ballistic missiles.

(17) **Holloman evaluates missile systems.** I. Stone. *Aviation Wk.*, **65** (6), 123–5, 127, 129, 131, 133, 137–8 (*Aug.* 6, 1956). Besides free-firing facilities Holloman Air Development Center has static test stands and research sections working on missile components.

One of the largest installations will be the 35,000-ft. captive missile test track on which speeds between Mach 3 and 4 will be attainable. The Aero Medical Field Laboratory is engaged on projects of interest in space-flight such as effect of cosmic rays and weightlessness. To test environmental control a sealed cabin will be flown to 80,000 ft. under a balloon for long periods.

(18) **Army shows missile arsenal; Redstone near field use.** D. A. Anderton. *Aviation Wk.*, **65** (16), 50–2 (*Oct.* 15, 1956). Some details of Dart, Lacrosse, Little John, Corporal, Honest John, Nike and, in particular, Redstone.

(19) **NACA'S Mach 10 rockets aid ICBM.** D. A. Anderton. *Aviation Wk.*, **65** (17), 52–4 (*Oct.* 22, 1956). Multi-stage solid rockets are being used to investigate heating problems in hypersonic flight. To reach high speeds in the denser atmosphere two stages are fired on the way up and the rest on the way down. Materials are also tested.

(20) **Army expands scope, challenges USAF.** C. Witze. *Aviation Wk.*, **65** (19), 32–3 (*Nov.* 5, 1956). Proposals for troop-carrying missiles and space stations for launching guided missiles.

ROCKET MOTORS

(21) **Stationary nuclear reactions in rockets.** E. Sänger. *Astronautica Acta*, **1**, 61–88 (1955). (*In German.*) Proposes that continuous nuclear reactions might be maintained in chambers tens of metres in diameter and operating at pressures of the order of 100 atm. Energy releases of 10^4 kcal m^{-3} $sec.^{-1}$ are possible at temperatures about 10^8 °K. Different methods of applying the energy of the reactor are discussed, pure atomic rockets and large static power plants seem the most likely. (*5 refs.*)

(22) **Safety valves.** De Havilland Engine Co., F. B. Halford and A. V. Cleaver. *Brit. Pat. No.* 743357 (*Jan.* 11, 1956). A pressure-relief valve, specifically for use on rocket motors.

(23) **Metal calalyst packs.** De Havilland Engine Co. *Brit. Pat. No.* 753658 (*July* 25, 1956). A pack, particularly for decomposing hydrogen peroxide, comprising several rows of transversely corrugated thin strip separated by thin plain strip to present a large surface area to the fluid.

(24) **Improvements relating to thrust augmentors for rocket motors.** Société Nationale d'Etude et de Construction de Moteurs d'Aviation. *Brit. Pat. No.* 756288 (*Sept.* 5, 1956). The inventors have shown that the augmentation obtained from a pulsating gas stream is higher than from a steady stream and they propose an augmentor in which the steady gas flow from a rocket is interrupted.

(25) **Rocket control.** Société Nationale d'Etude et de Construction de Moteurs d'Aviation. *Brit. Pat. No.* 757475 (*Sept.* 19, 1956). A method of varying a throat bullet in accordance with the propellant flow.

ROCKET PROPELLANTS

(26) **Energy, composition and exhaust velocity of chemical propellants for rockets, Part I.** A. Stettbacher. *Explosivstoffe*, **4**, 25–33 (1956). (*In German.*) Examples of calculation and tables of performance of various propellant mixtures based on liquid oxygen, nitric acid and hydrogen peroxide.

(27) **Rocket data at rocket speeds.** *Chem. Engng. News*, **34**, 5328 (*Oct.* 29, 1956). A digital analyser used at the U.S. Naval Ordnance Test Station for producing performance figures of solid propellants. Results are produced within seconds of a firing.

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NOTES AND NEWS

Payment of Subscriptions

We appeal to all members with bank accounts to pay their subscriptions by means of a Banker's Order. The saving to the Society is immense and members make a direct contribution to help our heavily over-burdened office if they adopt this practice. At present, the whole of the annual subscriptions are received in about three months and the work involved in dealing with receipts, queries, etc., is so great that it takes up the whole of each working day, with consequent dislocation of ordinary post and inconvenience to many members who expect to receive replies to letters and have their enquiries dealt with during this time. Payment through a bank dispenses with preparing receipts, writing up and agreeing dozens of cash book pages, checking and endorsing cheques, writing and stamping envelopes, and the issue of many hundreds of reminders, together with a great deal of additional correspondence and queries which might have been avoided, not counting the customary two or three hours' sojourn hunting through membership lists to try to identify an illegible signature—occasionally by a member who has changed his address without advising us, in which case the process of elimination becomes rather a protracted affair extending over a period of weeks or months.

Some three or four hundred members already remit by Banker's Order, but another thousand have bank accounts and could do so.

Won't *you* help us, *please*?

Barcelona Congress

The dates chosen for the Eighth Congress of the International Astronautical Federation to be held in Barcelona in 1957 are October 7-12.

G.f.W. Change of Name

On November 24, 1956, the G.f.W. changed its name to the *Deutsche Gesellschaft für Raketentichnik und Raumfahrt*. The new name does not involve any change in the objects of the G.f.W., but was taken because it was considered that, as spaceflight is not possible without rocket propulsion, greater emphasis must be made on problems of rocket technology.

Sixth Hermann Oberth Medal Award

The Sixth Hermann Oberth Medal has been awarded by the *Deutsche Gesellschaft für Rakententichnik und Raumfahrt* to Ing. Guido von Pirquet for his many contributions to astronautical thought, particularly in connection with the establishment of an artificial satellite.

Ing. von Pirquet is also an Honorary Fellow of the B.I.S.

North-West Branch Meetings

The North-West Branch has arranged for future meetings to be inserted in the "Announcements" column of the *Manchester Evening News* on the Friday immediately preceding each meeting.

NOTICES OF THE SOCIETY

The following elections were made at the Council Meeting of November 3, 1956:—

Fellows.

PAMELA JOAN BRADNEY, B.A., B.Sc., D.Ph., 2a, Maida Avenue, London, W.2.
JOHN RUSSELL BURCHALL, "Kenwood," Byfleet Road, West Weybridge, Surrey.
JOHN DEWHURST, 105, Manchester Road, Accrington, Lancs.
PETER MALCOLM FROGGATT, 1, Brunswick Road, Sutton, Surrey.
ARTHUR CECIL GEE, M.R.C.S., L.R.C.P., "East Keal," Romany Road, Oulton Broad, Lowestoft, Suffolk.
RONALD EDWIN VICTOR HAWKER, 36, Upper Cranbrook Road, Bristol, 6.
FREDERICK WILLIAM MALCOLM, B.Sc., 3, Cherrier Street, Saint Paul l'Ermite, Quebec, Canada.
VLADIMIR MALINOV, 11, David Street, Mount Carmel, Haifa, Israel.
ERNEST JOSEPH XAVER SELLNER, Dip.Ing., Mittermayerstrasse 11, Dachau, Munich, West Germany.
HEINRICH STRAUCH, 10, Marlowe Road, Cambridge.
JOHN STRINGER, 126, Minster Road, Westgate-on-Sea.
NORMAN ALFRED THROP, 29, Northwood Gardens, Greenford, Middlesex.
ALFRED HENRY WHITAKER, Box 713, c/o B.A.P.C.O., Awali, Bahrain, Persian Gulf.

Senior Members.

NAFTALI HERZ ENGELHARD, 68, West Side, Clapham Common, London, S.W.4.
FRANCIS JOHN FIELD, 79, Lichfield Road, Sutton Coldfield.
LAURENCE GREENWOOD, 21, Bull Pond Lane, Dunstable, Beds.
RALEIGH GEORGE HOLLINGBERY, 126, Lexham Gardens, London, W.8.
KENNETH GORDON VILLETTE MILES, Birch Platt, West End, Woking, Surrey.
WILLIAM GEORGE TRILLE, 26, Queens Road, Southall, Middlesex.
REX STEPHEN WILKINSON, 80, Gilling Court, Belsize Grove, N.W.3.

Members.

DUANE EDWARD ATKINSON, B.S., 10, W. Orange Avenue, South San Francisco, California, U.S.A.
JOHN LESLIE BOYCE, c/o Lady Boyce, No. 1, Keynsham Road, Cheltenham, Glos.
DENNIS, ARTHUR BULLOCK, 984, Sutton Road, Hull.
DAVID FRANCIS CARTER, 2, Peterborough Gardens, Ilford, Essex.
JOHN MICHAEL CLARKE, "The Knoll," Burton Road, Littleover, Derby.
EDWARD MARK DOWLEN, D.L.C., D.C.Ae., 5, Grove Avenue, Harpenden, Herts.
ROBERT FRANK EMMERSON, Wellington House, 30, Greenside, Waterbeach, Cambs.
AUSTIN EVANS, 37, Richard Road, Rotherham.
WILLIAM H. FINLAY, Box 31, G.P.O., Canberra, A.C.T., Australia.
SYLVIA FROGGATT, 1, Brunswick Road, Sutton, Surrey.
GARY WENDELL GUTHRIE, 2042, Rankin Avenue, Columbus, 19, Ohio, U.S.A.
TIMOTHY RICHARD CORY HASSALL, The Manor House, Wheatley, Oxford.
RAYMOND JOHN HOLLIDAY, 32, Franklands Drive, Coomblands, Addlestone, Surrey.
BERNERD HOLMES, 1a, East Road, Wharley End, Cranfield, Bletchley, Bucks.
AVRO MANHATTAN, 24, Ausdell Terrace, W.8.
SUSAN MARY MARTIN, The Manor Lodge, Piddletrenthide, Dorset.
RALPH J. MARX, 12754, Bessermer St., North Hollywood, California, U.S.A.
JAMES BENNETT MCINNES, B.Sc., 3, Cornwallis Place, Edinburgh, 3.
JOHN CHRISTOPHER PARR, B.Sc.(Eng.), 68, Compton Road, London, N.21.
JOHN HERMAN SMID, Heemsteedse Dreef 153, Heemstede, Holland.
FRANCIS HARRY THORNTON, F.R.A.S., Grove Mount, Navenham, Northwich, Cheshire.
GEOFFREY FAULKNER WADDINGTON, 4, Wheatlands Road, Harrogate.
ALAN WRIGHT, 18, Beadon Avenue, Waterloo, Huddersfield, Yorks.

The following elections were made at the Council Meeting of December 1, 1956:—

Fellows.

HERBERT WHITMORE BAKER, B.Sc., A.M.I.E.E., 62, Bankhurst Road, Catford, S.E.6.
Major LAWRENCE FREDERICK BALL, Highfield Place, Mount Pleasant Road, Ealing, W.5.

JOHN JOSEPH BROGAN, B.Mech.Eng., 15021, Fruitvale Avenue, Saratoga, Calif., U.S.A.
JAMES OLIVER CLARK, B.Eng., 8, Ancaster Road, West Park, Leeds 16, Yorkshire.
TADEUSZ DOBROWOLSKI, M.Sc., ul. Hoza 69, Warszawa, Poland.
WALTER JOHNSTON, B.Sc., Goose Rye Lodge, Worplesdon, Surrey.
ARTHUR WILLIAM FREDERICK METZ, 8, Byfield Road, Coventry, Warwickshire.
COLIN HARKER MORRIS, 36, Beverley Avenue, Mount Royal, Montreal, Quebec, Canada.
ALEXANDER GORDON SMITH, B.Sc., "Rosemount," Cambusdoon Drive, Alloway, Ayr, Scotland.
WILLIAM DOUGLAS VIETS, 192, Edendale Street, Springfield 4, Massachusetts, U.S.A.

Senior Members.

EARLE JAMES ANDREW, 240, Churchill Avenue, Ottawa 3, Ontario, Canada.
DOUGLAS VINCENT DANIELS, T 14, Castle Farm, Dedworth, Windsor, Berkshire.
RODNEY ALAN WYATT PAUL, Rotharini, Njoro, Kenya.

Members.

WILBERT LIN SUNG AU, Central Dorm., Box 141, Corvallis, Oregon.
LUIZ DE GONZAGA BEVILACQUA, Rua Saint Martin 20–27, Baura—Sao Paulo, Brazil.
EDWARD H. CARTER, B.Sc., 8201, Aura Avenue, Reseda, Calif., U.S.A.
PHILIP JOHN DICKINSON, 23, Hasborough Road, Folkestone, Kent.
MICHAEL DAVID FACER, 500, Hitchin Road, Luton, Bedfordshire.
DALE A. FURLONG, B.Sc., 22204, Fairview Drive, P.O. Box 91, Canuga Park, Calif., U.S.A.
FRANK J. GAFFNEY, B.Eng., 11704, Pearwood Avenue, San Fernando, Calif., U.S.A.
WILLIAM B. MABE, B.Sc., 19954, Acre Street, North Ridge, Calif., U.S.A.
JAMES C. MATHESON, M.Sc., B.Sc., P.O. Box 91, Canoga Park, Calif., U.S.A.
JOHN STUART NELSON, 41, Sidney Road, Walton-on-Thames, Surrey.
MICHAEL WILLIAM PASTORE, 9, John Peel Road, West Simsbury, Connecticut, U.S.A.
BARTON SEBRING PULLING, B.A., Haus 4226, Turenne Kaserne (Kreuzberg), Zweibrucken, West Germany.
GEOFFREY MICHAEL TUCKER, Flat 8, 97, Greencroft Gardens, N.W.6.

The following elections were made at the Council Meeting of January 5, 1957:—

Fellows.

GEORGE ROBERT ADAMS, A.R.I.B.A., 11, Broad Elms Lane, Sheffield, Yorks.
MORTON ALPERIN, Ph.D., M.Sc., B.Eng., 489, Bellefintaine Street, Pasadena, Calif., U.S.A.
ERLING BUCH ANDERSEN, Aabakkevej 27, Copenhagen, Denmark.
PHILIP JOHN DICKINSON, 23, Hasborough Road, Folkestone, Kent.
NOEL THOMAS GALLAGHER, B.Sc., 25, Stanhope Gardens, London, S.W.7.
JACK ANTHONY LASPADA, M.S., B.S., 108, Cambridge Court, New Orleans, 14, La., U.S.A.
RICHARD HUGH GODFREY LYNE-PIRKIS, M.A.(Cantab.)., M.B.B.Clin.(Cantab.), M.R.C.P., D.Ch., Ockford Hill, Godalming, Surrey.
DONALD ERNEST MANSFIELD, 10, Lyndhurst Drive, Leyton, London, E.10.
ARNOLD WILLIAM MORLEY, Ph.D., M.Sc., B.Sc., 34, Ladygate Lane, Ruislip, Middx.
FEDERICO ROMANO, Dip. Ing., Woodside Lodge, Woodside, Aspley Guise, Bletchley, Bucks.
FRANCIS ERNEST VIVARES TABART, 65, Hesters Way Road, Cheltenham, Glos.
DAVID COCKBURN WALLIS, 44, Parkfield Avenue, Hillingdon, Middx.

Senior Members.

FRANK MURRAY AMBLER, 16, Ethelred Road, West Worthing, Sussex.
JOSEPH ADAM CLARKE, 48, South Street, Lewes, Sussex.
PETER JOSEPH HENNIKER-HEATON, 100, Memorial Drive, Cambridge, Mass., U.S.A.
NORMAN ROBSON NICOLL, 93, Leighswood Avenue, Aldridge, South Staffs.
RALPH WILLIAM PARISH, 274, Ipswich Road, Colchester, Essex.
HARRY ANTHONY GROSVENOR WRIGHT, 80, Bristol Road, Birmingham 5.

Members.

HANS CHRISTIAN ANDERSON, c/o 47, Trajan Avenue, South Shields, Co. Durham.
JOHN STAFFORD BONNER, 14, Links View Road, Shirley, Croydon, Surrey.
ALFRED JOSEPH BOYCE, Beethovenstraat 93, Amsterdam, Holland.
DEREK HENRY BRIGGS, 22, Grey Street, Middleton, nr. Manchester, Lancs.
BENJAMIN GEORGE ALFRED CLARK, 53, Normandy Road, London, S.W.9.
ROBERT VILLIERS BRISCOE CONNELL, 50, Palewell Park, East Sheen, S.W.14.
JOHN STANLEY CUTHBERT, 41, Abbotswood Road, Luton, Bedfordshire.
PETER LEONARD DURBIN, Mangatoetoe Road, R.D. 111, Kaitaia, Northland, N.Z.
JOHN EDEN, 15, Barrington Court, Dorking, Surrey.
LEONARD BROOKE EDWARDS, 25, Palmeira Avenue, Hove 3, Sussex.
FRANCIS GILES, 163, Elm Road, New Malden, Surrey.
OSCAR GITTINS, c/o Diplomatic Wireless Service, Foreign Office, London, S.W.1.
DAVID GRIFFITHS, 64, Coniston Avenue, Headington, Oxford.
FRANK HAMPSON, Bayford Lodge, 1, College Avenue, Epsom, Surrey.
ROBERT THOMPSON HOLMES, 32, Caerlaverock Avenue, Prestwick, Ayrshire.
EDWARD CHRISTOPHER HORAN, "Rosemont," Southwood Avenue, Ottershaw, Chertsey, Surrey.
RAYMOND ALBERT KNELLER, 8, Glenacre Drive, Castlemilk, Glasgow, S.5.
LOUIS DAVID WILLIAM KOTTRITSCH, 4, Gosport Road, Walthamstow, London, E.17.
FERDI WILHELM MORITZ KUHLMANN, 5, Blackhorse Crescent, Amersham, Bucks.
JOHN EDWARDS LE BROCQ, "The Nest," Links Road, Blyth, Northumberland.
DEREK AYLMER LESLIE, P.O. Box 9, Whakatane, New Zealand.
JOHN ARTHUR WILLIAM MCDONALD, Officers' Mess, R.A.F., Dyce, Aberdeenshire.
WILLIAM JOSEPH MORRIS, 19, Strowbridge Street, Trumansburg, New York, U.S.A.
JACK MURPHY, 23, Fryergate, Alverthorpe Road, Wakefield, Yorks.
ALAN HUGH OGDEN, 2, Alexandra Road, Clifton, Bristol, 8.
LUMSDEN FOLEY ONSLOW, 40, Sherborne Court, Anerley, London, S.E.20.
ANTHONY WILLIAM PEARSON, 45, Parkstone Road, Beverley High Road, Hull, Yorks.
ERNEST GEORGE PHILPOT, "Vidor," Channel Way, Fairlight, Hastings, Sussex.
PETER POSTLETHWAITE, 65, Nest Estate, Mytholmroyd, nr. Halifax, Yorks.
REGINALD RIDE, 2, Belle Vue Terrace, Bellerby, Leyburn, Yorks.
JOHN EDWARD ROBINSON, 10, Marlott Road, Windhill, Shipley, Yorks.
ANTHONY GEORGE ROGERS, 24, Rose Glen, Kingsbury, London, N.W.9.
RONNIE JAMES SCROGGIN, 496, South Cleveland Avenue, Bradly, Illinois, U.S.A.
GEORGE SMITH, 2, Charlotte Terrace, Chilton, nr. Ferryhill, Co. Durham.
GEOFFREY STRACK, 55, Falkland Road, Hornsey, London, N.8.
JANUSZ THOR, Dip.Ing., ul Kredytowa 6, m 25, Warsaw, Poland.
RAYMOND MERVYN WELLS, B.A., M.A., F.R.Met.S., 4867A, Carlton Avenue, Montreal 26, P.Q., Canada.
ALAN ROGER WHITE, 24, School Lane, Bidston, Birkenhead, Cheshire.
ROBERT WAYNE WILSON, 1720, Kimberley Drive, Sunnyvale, Calif., U.S.A.

Obituary.

The Council regret to record the death of Flt. Lt. Leslie Arthur Coe, aged 34, who lost his life as a result of an air crash in September last.

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Twelfth Annual General Meeting

of the

British Interplanetary Society

Limited (by Guarantee)

NOTICE IS HEREBY GIVEN that the TWELFTH ANNUAL GENERAL MEETING of the BRITISH INTERPLANETARY SOCIETY will be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1, on SATURDAY, May 18, 1957 at 6 o'clock in the evening precisely, for the transaction of the business specified in the Agenda below.

AGENDA

1. To hear the Chairman's Address.
2. To receive the annual statement of accounts and balance sheet for the year ended September 30, 1956, and the auditor's report thereon.
3. To elect four Members of the Council of the Society. In accordance with the provisions of Article 15, the following four Members of the Council will retire at the meeting, and offer themselves for re-election:—

   D. J. Cashmore. J. Humphries. L. R. Shepherd. H. P. Wilkins.

   No other additional names have been nominated but if the number of nominations exceeds the number of vacancies, election will be by postal ballot. The last date for the receipt of nominations is April 6, 1957.
4. General discussion of the affairs of the Society during the past year.
5. Any other business.

By order of the Council,

L. J. CARTER,

Secretary.

A member who cannot be personally present at the meeting may appoint by proxy some other person (who must be a member of the Society) to attend and vote on his behalf, subject, however, to the limitation that a proxy cannot vote except on a poll.

Following the Annual General Meeting will be a "Brains Trust" when several leading Fellows of the Society will answer questions and engage in discussion on the Artificial Satellite project and Space Flight generally.

The British Interplanetary Society

Limited (by Guarantee)

INCOME AND EXPENDITURE ACCOUNT for the year ended September 30, 1956

1955 £	Expenditure.	£ s. d.	£ s. d.
	To Office and Management Expenses—		
235	Rent, Light, Heat, Cleaning and Insurance	250 17 11	
533	Salaries and National Insurance	815 7 0	
486	Postage, Stationery, Telephone and Telegrams	539 12 4	
103	Publicity and Advertising ..	167 8 2	
203	Travelling and Entertaining Expenses	203 7 7	
89	Library Expenses	48 12 9	
122	Sundry Expenses	64 12 4	
1,771			2,089 18 1
2,630	" **Publications**		2,317 1 8
412	" **Expenses of Meetings** ..		447 16 7
	" **International Astronautical Federation—**		
195	Contribution and Expenses ..		313 17 5
37	" **Income Tax**		90 6 6
	" **Depreciation of—**		
97	Furniture and Equipment ..		65 13 6
500	" **Transfer to General Reserve**		– – –
471	" **Excess of Income over Expenditure** for year carried to Accumulated Fund		1,276 4 5
6,113			6,600 18 2

1955 £	Income.	£ s. d.
	By Membership Subscriptions and Entrance Fees	
5,023		5,301 4 6
325	" **Donations**	334 12 3
478	" **Library Subscriptions and Sale of Journals**	604 4 9
	" **Income from Investments—**	
35	3½% Defence Bonds	35 0 0
42	" **Deposit Account Interest**	144 2 0
210	" **Sundry Receipts**	181 14 8
6,113		6,600 18 2

BALANCE SHEET as at September 30, 1956

BALANCE SHEET as at September 30, 1956

1955 £	Capital and Reserves.	£ s. d.	£ s. d.
	Accumulated Fund—		
2,099	Balance at September 30, 1955	4,069 18 2	
1,500	*Add* General Reserve	— — —	
471	Excess of Income over Expenditure for year to September 30, 1956 ..	1,276 4 5	
4,070			5,346 2 7
1,361	**Compounded Subscriptions Reserve**		1,437 0 0
—	**Yorkshire Branch: Observer Fund**		30 2 6
58	**Income Tax Reserve**		113 1 0
5,489	Total of Capital and Reserves		6,926 6 1
	Current Liabilities.		
	Income Tax 1954/56	35 2 6	
321	**Subscriptions Paid in Advance**	289 8 9	
149	**Sundry Creditors**	632 0 10	
			956 12 1
	Certified to be a true copy— L. R. SHEPHERD, G. V. E. THOMPSON } *Members of the Council.* L. J. CARTER, *Secretary.*		
5,959			7,882 18 2

1955 £	Fixed Assets.	£ s. d.	£ s. d.
	Furniture and Equipment—		
1,355	At Cost	1,381 10 6	
515	*Less* Depreciation	581 10 6	
840			800 0 0
	Library—		
422	At Cost	422 18 2	
322	*Less* Depreciation	322 18 2	
100			100 0 0
	Investments—		
1,000	3½% Defence Bonds (P.O. Issue)		1,000 0 0
1,940	Total of Fixed Assets ..		1,900 0 0
	Current Assets.		
50	**Stock of Badges**	20 0 0	
46	**Sundry Debtors**	108 13 2	
53	**Payments made in Advance** ..	67 12 0	
	Cash at Bank—		
3,000	Deposit Account	4,532 0 0	
846	Current Account	1,172 8 5	
24	**Cash in Hand**	82 4 7	
			5,982 18 2
5,959			7,882 18 2

REPORT OF THE AUDITOR TO THE MEMBERS OF THE BRITISH INTERPLANETARY SOCIETY

I have obtained all the information and explanations which to the best of my knowledge and belief were necessary for the purposes of my audit. In my opinion proper books of account have been kept by the Society so far as appears from my examination of those books. I have examined the above Balance Sheet and annexed Income and Expenditure Account which are in agreement with the books of account. In my opinion and to the best of my information and according to the explanations given to me, the said accounts give the information required by the Companies Act, 1948, in the manner so required, and the Balance Sheet gives a true and fair view of the state of the Society's affairs as at September 30, 1956, and the Income and Expenditure Account gives a true and fair view of the surplus of income over expenditure for the year ended on that date.

35, Brian Avenue,
Sanderstead, Surrey.

January 1, 1957.

T. W. WOODS,
Incorporated Accountant.

REALITIES OF SPACE TRAVEL

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The main subject headings are:

1. Introduction to Astronautics.
2. The Satellite Vehicle.
3. Interplanetary Flight.
4. Physical Factors in Spaceflight.
5. Biological Aspects of Spaceflight.
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